Laboratory evaluation of six modified formulations of Tracer® (spinosad) against laboratory-reared *Melanoplus sanguinipes* and three field-collected species of grasshoppers

K. Chris Reuter, R. Nelson Foster, Lonnie R. Black and Larry E. Jech

October 2007

October, 2007

Laboratory evaluation of six modified formulations of Tracer® (spinosad) against laboratory-reared *Melanoplus sanguinipes* and three field-collected species of grasshoppers

K. Chris Reuter, R. Nelson Foster, Lonnie R. Black and Larry E. Jech

USDA-APHIS-PPQ-CPHST Phoenix Laboratory-Arizona

Cooperators:

Mark Hertline, Ray Boucher and Doris Paroonagain, Dow AgroSciences
Agenor Mafra-Neto and Reginald Cooler, ISCA Technologies
Jack Jenkins, Pacific Biocontrol Corporation

Abstract

We evaluated five modified formulations of Tracer®, containing the active ingredient spinosad, to determine if residual activity could be extended on laboratory-sprayed pots of range grass as compared with the standard Tracer® formulation. This study is a follow-up to field cage studies with the same formulations conducted in July 2007 near Edgemont, South Dakota. We conducted the laboratory study three times over a period of six months, using four different grasshopper species. The species included field-collected *Phoetaliotes nebrascensis*, *Melanoplus gladstoni*, *Melanoplus lakinus* and laboratory-reared *Melanoplus sanguinipes*. Numbers of treatments and species used varied due to the availability of particular grasshopper species. Unusually high mortality in the untreated population prevented us from making statistically significant comparisons in any of the three studies.

Introduction

Tracer® is a fermentation-derived insect control agent registered for pest control in cotton, field corn, sorghum, soybeans, small grains and tobacco. The formulation contains the active ingredient spinosad (a mixture of spinosyn A and spinosyn D).

Spinosad works by contact and ingestion, but control by means of ingestion is 5-10 times more effective (Dow AgroSciences). In past studies, spinosad doses of 105 and 210g AI/ha (3 and 6 fluid oz/acre) showed excellent control of grasshoppers when aerially applied to small acreages of rangeland. High product cost at these rates would preclude these treatments from being used for typical rangeland grasshopper control measures. Also, this product exhibits a rather short residual period, with activity diminishing between 0 and 7 days after treatment with the lower dose (Foster et al. 2002). In this study we will attempt to extend the residual activity of a lower dose of Tracer® by modifying the formulation with various components, including a pheromone formulation used against pink bollworm and gypsy moth that reportedly extends the persistence of that product. During the original field study in July 2007, we encountered heavy rainfall totaling 5.49 cm (2.16 in.) at 1-5 days after treatments were applied (Foster et al. 2007). We believe this event negatively impacted initial mortality and subsequently affected extended persistence of the modified formulations. For these reasons, we proposed the following laboratory bioassay to generate additional data.

Objectives

- Demonstrate that the length of residual activity of spinosad can be extended by modifying the formulation.
- Evaluate and compare FAASSTT (Field Aerial Application Spray Simulation Tower Technique) applications of six formulations containing spinosad for initial and extended activity against grasshoppers confined on pots of range grass.
- Determine if extended residual activity improves overall mortality.

Materials and Methods

Six different formulations containing spinosad were evaluated in these laboratory studies. The following components were incorporated into the formulations in anticipation of extending the persistence of the standard formulation, Tracer: (1) Nu-Lure (a proteinaceous liquid designed for use as an attractant and bait in insecticide sprays, Miller Chemical and Fertilizer Corp.), (2) ISCA Technologies, (3) 3% Grandma's Unsulphured molasses and Nalcotrol (an anti-drift spray adjuvant), (4) NAF (26% spinosad wettable granular formulation provided by Dow AgroScience) and (5) a pink bollworm pheromone formulation provided by Pacific Biocontrol. All of the formulations were applied at 9.35 liters/ha (one gallon/acre) total volume equivalent and contained 52.6g AI spinosad/ha (0.05lb AI/acre). In the associated graphs, treatments are referred to as: **Tracer**, **Nu-Lure**, ISCA Technologies as **ISCA**, Grandma's Unsulphured molasses and Nalcotrol as **Mol/Nalcotrol**, **NAF**, Pacific Biocontrol formulation as **PBC** and untreated control as **UTC.**

The treatments were applied using the fixed spray tower version of Field Aerial Application Spray Simulation Tower Technology (FAASSTT) in a laboratory setting (Figure 1). Specifically, spray treatments were injected into a Paasche Type H airbrush with modified syringe needles to produce droplets that simulate aerial sprays. These sprays were applied to plant pots of mixed range grass containing 50% western wheatgrass (*Agropyron smithii*), 40% buffalo grass (*Bouteloua dactyloides*) and 10% blue grama (*Bouteloua gracilis*). Treatments were replicated four times with two cages of five grasshoppers each constituting one replication. Grasshoppers were confined on the grass at 0, 4, 8, 12 and 16 days after treatment. Grass pots intended for 4, 8, 12 and 16 days residual were placed outdoors for the appropriate period of time to simulate exposure to rangeland environmental conditions (Figure 2).

Test insects were selected from holding cages containing either field collected (from the San Carlos Indian Reservation, AZ) or laboratory-reared (from ARS, Sidney, MT colony) grasshoppers. Field collected species included the largeheaded grasshopper, *Phoetaliotes nebrascensis* (Thomas), the Gladston grasshopper, *Melanoplus gladstoni* Scudder and the Lakin grasshopper, *Melanoplus lakinus* (Scudder). The laboratory colony species used was the migratory grasshopper, *Melanoplus sanguinipes* (Fabricius). After spraying grass pots in groups of two, grasshoppers were immediately placed in cages (10.5 x 10.5 x 9cm plant pot fitted with 9.5cm ID x 35cm cylinder created from clear extruded tubing) for the 0 day residual treatment. The cages were kept in a holding room maintained at 26-27° C (80-82° F) and a 14:10 light:dark photoperiod. Subsequently, at 4, 8, 12 and 16 days after spraying, grasshoppers were placed in the appropriate cages in the holding room on grass pots that had outdoor exposure and monitored daily for mortality (Figure 3).

The experimental plan was a completely randomized design with grasshoppers being assigned to groups (treatments) indiscriminately. An arcsine transformation of the data was performed prior to evaluation by a Multivariate Analysis of Variance (MANOVA) with a repeated measures response.

Results and Discussion

First Study: *Phoetaliotes nebrascensis* and *Melanoplus gladstoni* – 11 October 2007
Due to unusually high mortality in the untreated cages, none of the treatments produced mortality that was significantly superior to the untreated population (Figures 4-8). Since the grasshoppers were not sprayed directly, ingestion of the treated grass was expected to produce most of the mortality. Lack of success in this study could be traced to the use of field collected grasshoppers, which for whatever reason, did not adapt well to laboratory conditions and confinement in the cages with grass. *P. nebrascensis* is a strict grass feeder and *M. gladstoni* is a mixed feeder with a preference for forbs. In addition to the grass provided for the test insects, supplemental food in the form of TetraMin® aquarium fish food (flakes) and Cheerios® cereal was added to each cage initially.

Approximately two weeks into the study, we started to find grasshoppers with fungal infections. This may have been a result of high humidity in the room, possibly due to excessive soil moisture in the cages. At this point, we placed a dehumidifier in the room in an attempt to reduce the humidity level. As a result, we also stopped supplementing the cages with fish food and cereal as it was attracting fungal growth.

Second study: *Melanoplus gladstoni* – 02 November 2007
Once again, due to unusually high mortality in the untreated cages, none of the treatments produced mortality that was significantly superior to the untreated population (Figures 9-13). In this study, we decided to forego the fish food and cereal and supplement with Romaine lettuce after 4 days. The lettuce was treated with a spray solution of Fumagilin-B, an antibiotic primarily used to prevent *Nosema apis* in bee colonies, before adding to cages.

Third Study: *Melanoplus sanguinipes* – 07 March 2008
Again we had high mortality in the untreated population confounding results and making it difficult to produce any statistically significant comparisons (Figures 14-18). Possible reasons for the lack of difference between treated and untreated populations are: (1) the laboratory-reared grasshoppers from an established colony were in decline and (2) this particular species is classified as a mixed feeder with a preference for forbs rather than the range grasses used in this study.

Overall, the problems we encountered were likely procedural in nature, rather than the inability of spinosad to kill grasshoppers. As previously stated, we expected most of the mortality to come from ingestion of the treated vegetation. It seems likely that with the adverse conditions in the cages the grasshoppers were not feeding normally, possibly due to illness from fungal pathogens or lack of suitable vegetation.

References

Dow AgroSciences, product brochure

Foster, R. Nelson, K. Chris Reuter, Bruce Helbig, Cheryl Huddleston, and Nathan Bradley. 2002. Initial evaluations of malathion and Spinosad formulations for control of grasshoppers on rangeland in South Dakota. Final Report. December 2002. USDA, APHIS, PPQ, CPHST, DS&PMSL, Phoenix, Az. 17 pp.

Foster, R. Nelson, K. Chris Reuter, Lonnie R. Black, Bruce Helbig, Cheryl Huddleston, David Cowan and Daryl Hill. 2007. Increasing the field activity period of spinosad against rangeland grasshoppers: Field evaluation of initial mortality and residual activity of six formulations. Final Report. December 2007. USDA, APHIS, PPQ, CPHST, Phoenix Laboratory, Arizona. 31 pp.

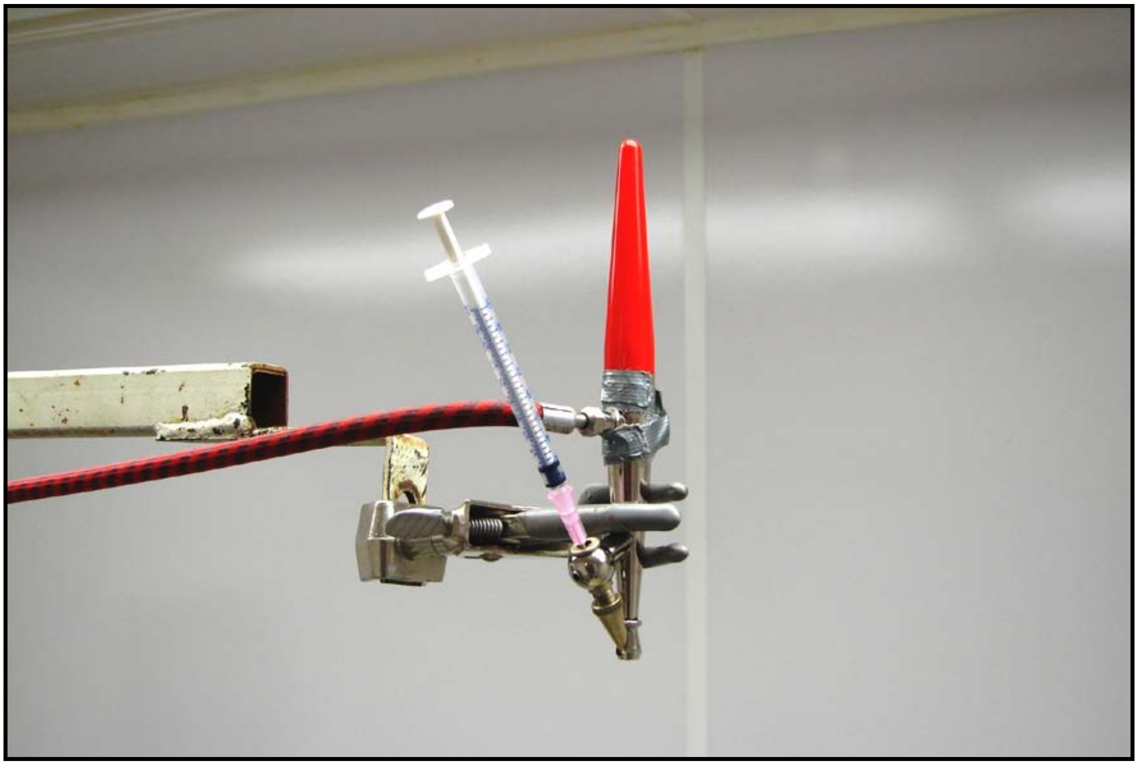

Figure 1. Fixed **Field Aerial Application Spray Simulation Tower Technique (FAASSTT)** system with modified airbrush and syringe.

Figure 2. Treated grass pots placed outdoors to simulate rangeland environmental exposure.

Figure 3. Cages used to confine grasshoppers on treated grass, maintained and monitored in a climate-controlled room.

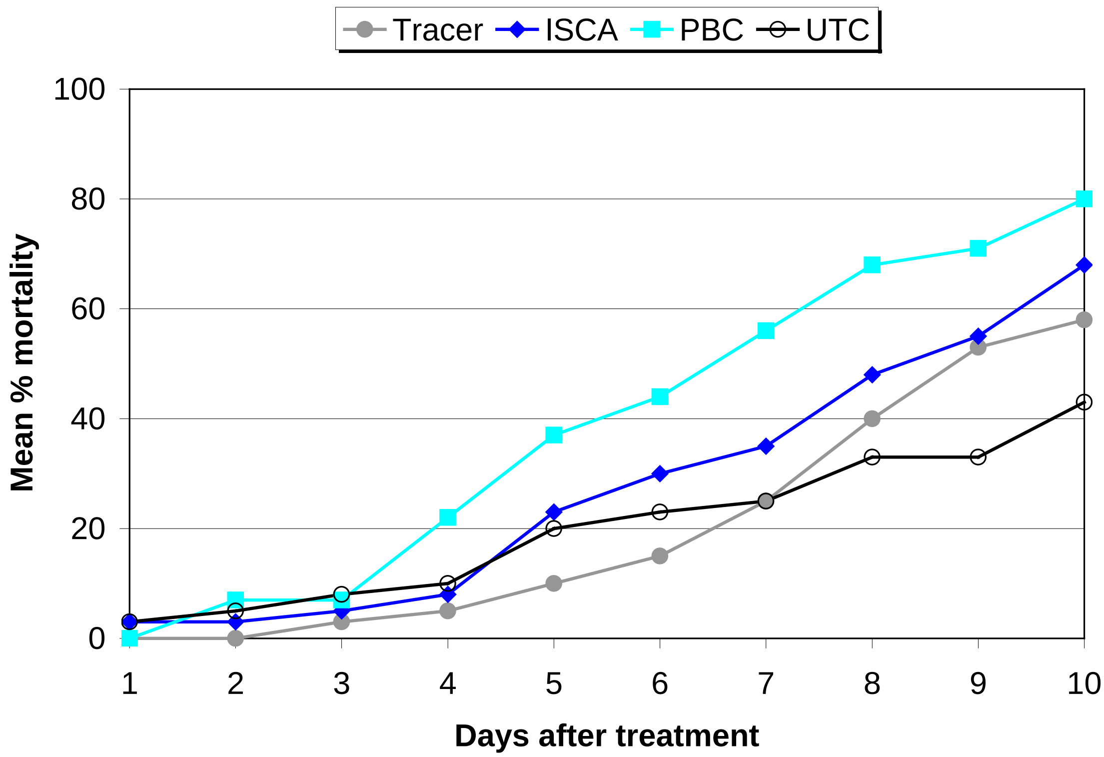

Figure 4. **0 day** residual on grass vs. adult *Phoetaliotes nebrascensis* grasshoppers.

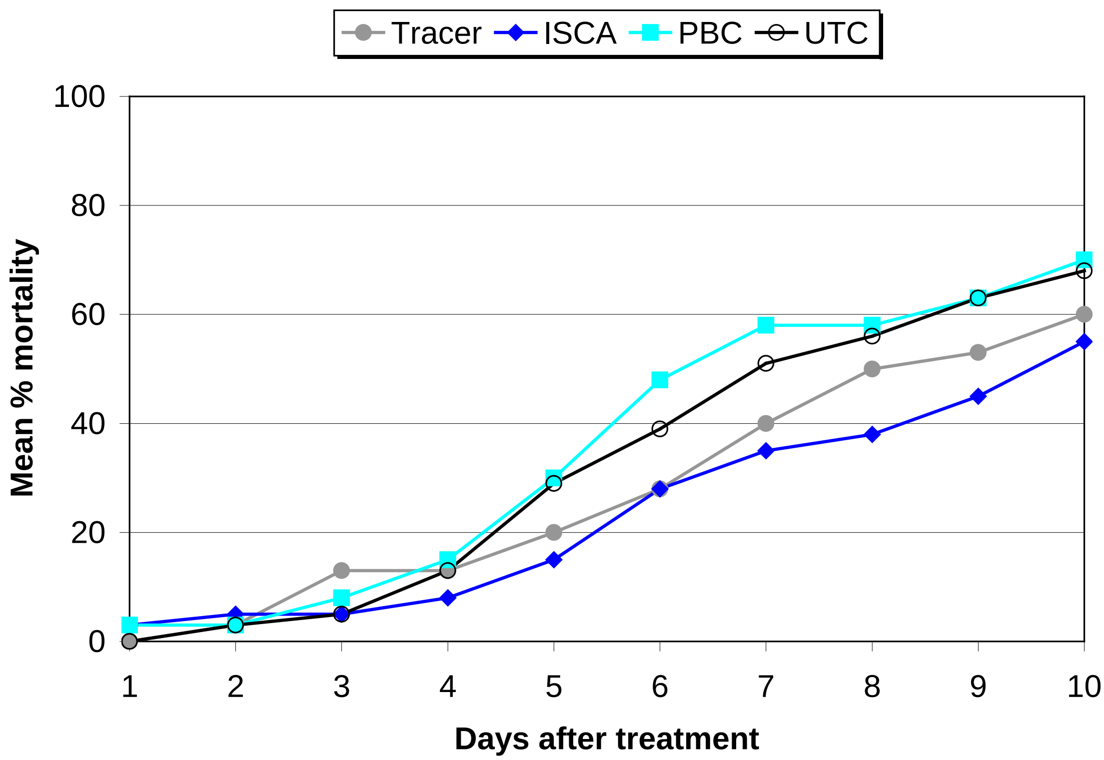

Figure 5**. 4 day** residual on grass vs. adult *Phoetaliotes nebrascensis* grasshoppers.

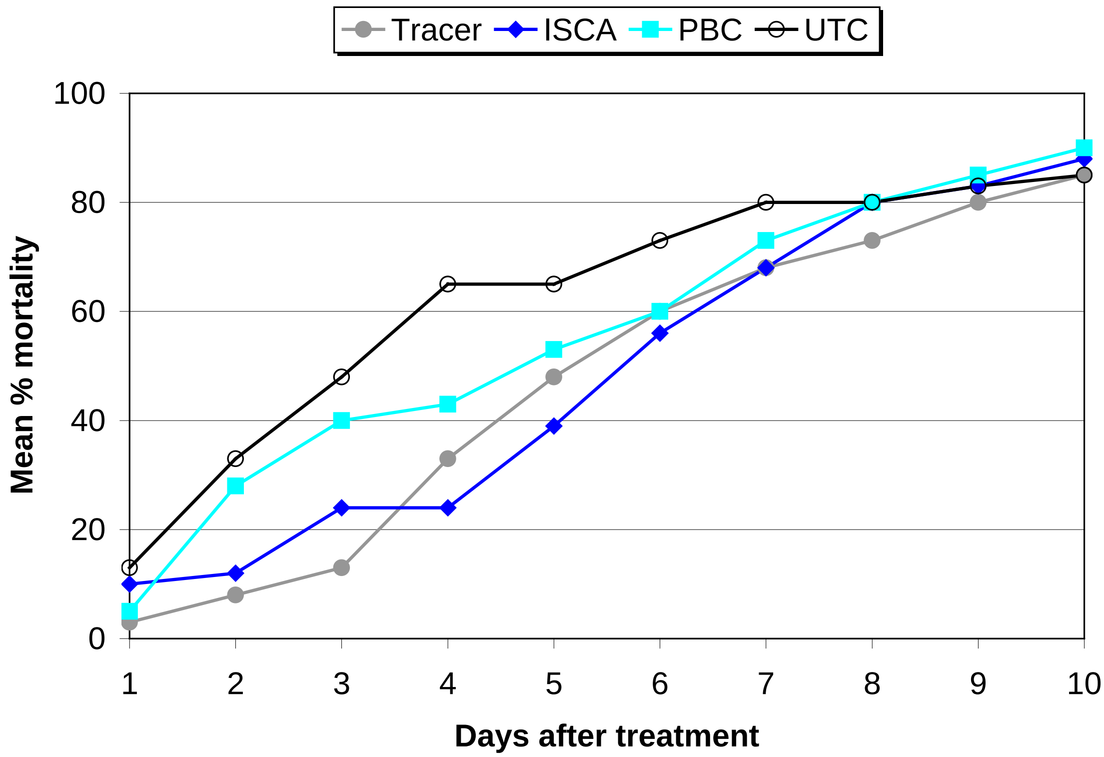

Figure 6. **8 day** residual on grass vs. adult *Phoetaliotes nebrascensis* grasshoppers.

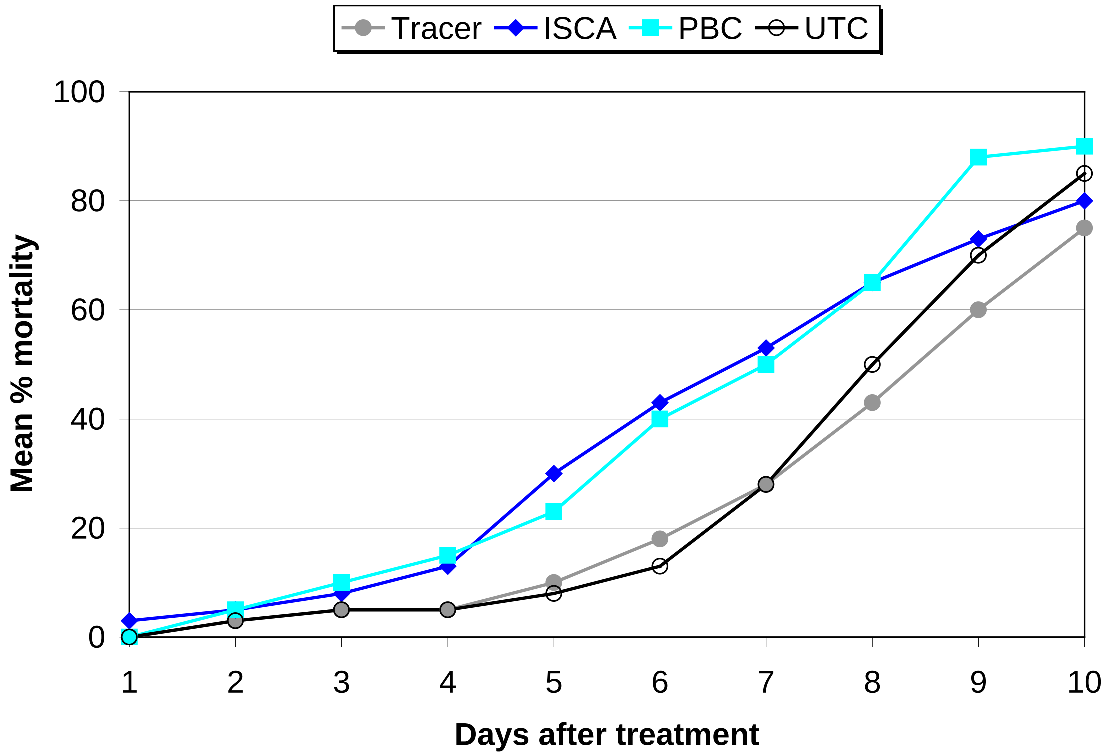

Figure 7. **12 day** residual on grass vs. adult *Phoetaliotes nebrascensis* grasshoppers.

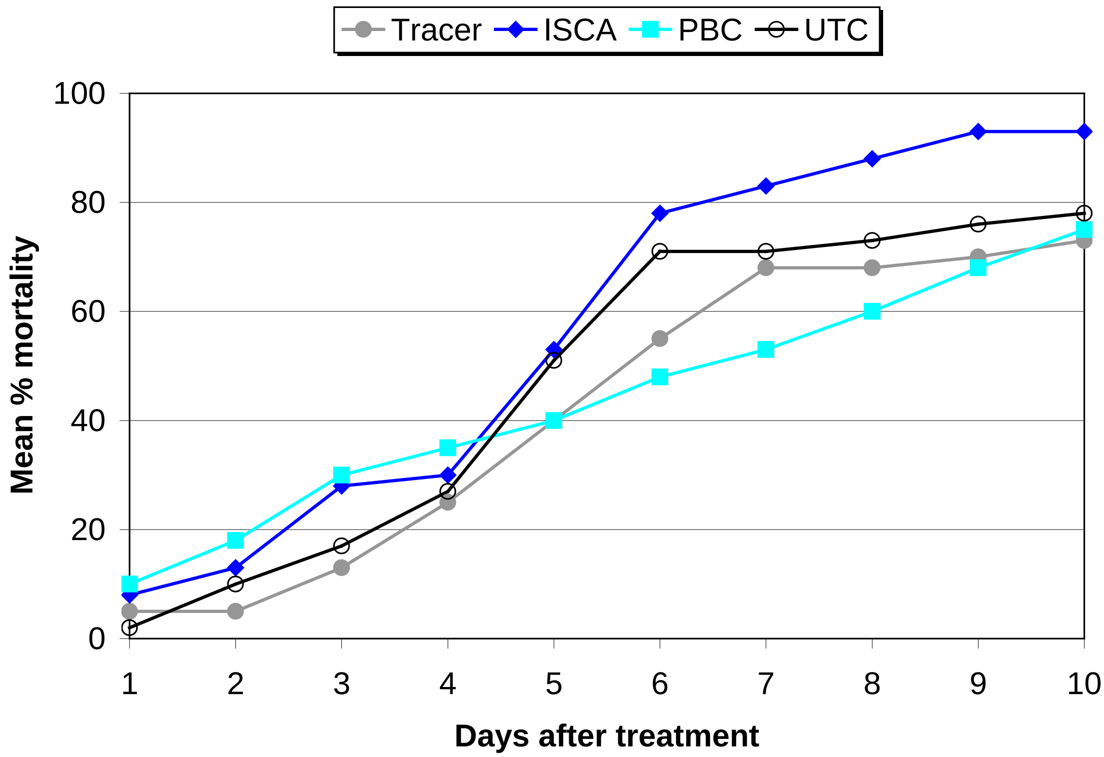

Figure 8. **16 day** residual on grass vs. adult *Phoetaliotes nebrascensis* grasshoppers.

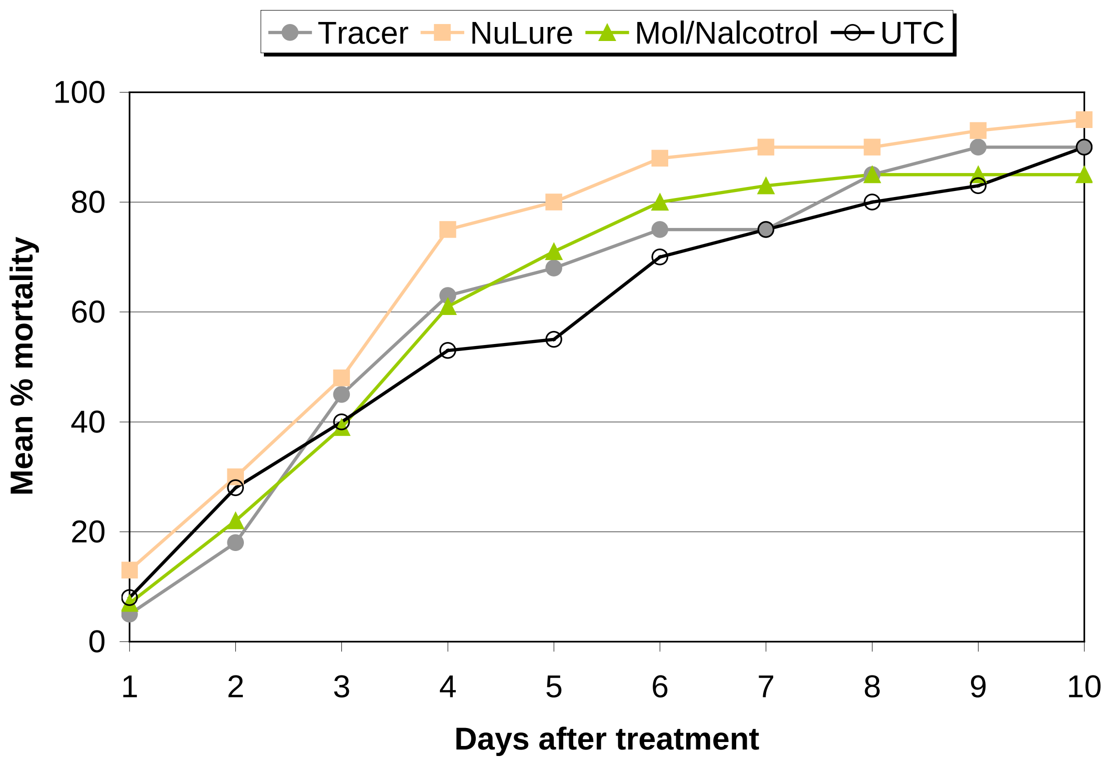

Figure 9. **0 day** residual on grass vs. adult *Melanoplus gladstoni* grasshoppers.

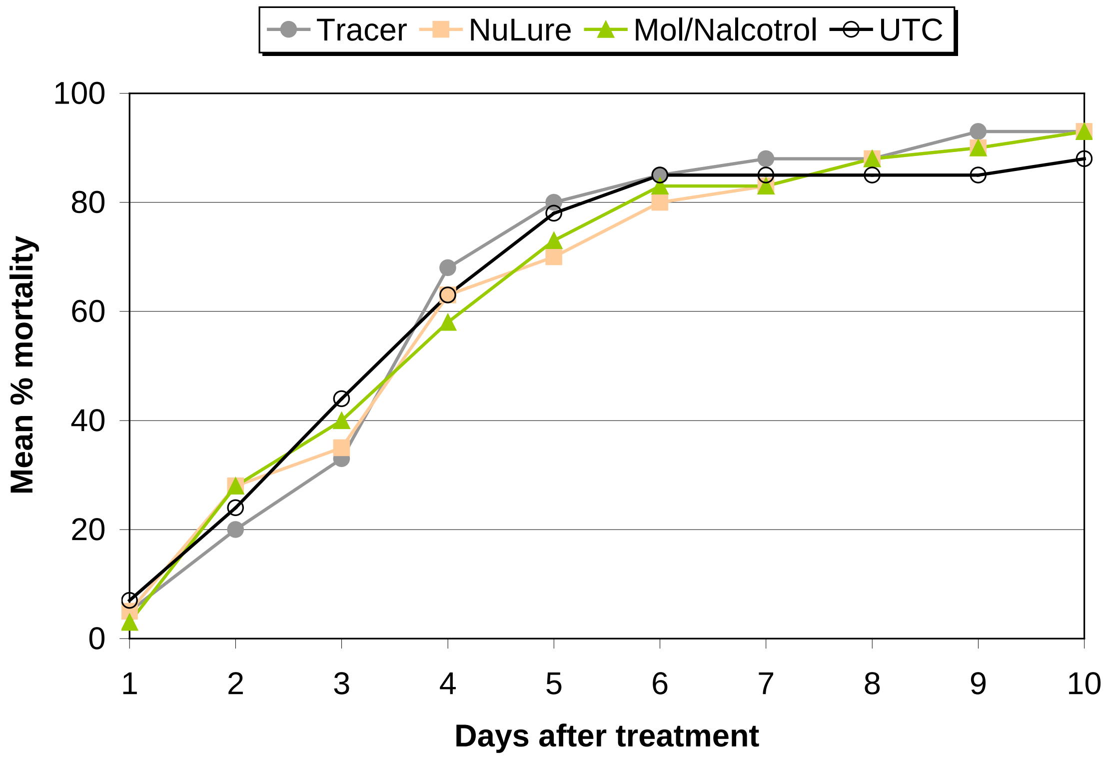

Figure 10. **4 day** residual on grass vs. adult *Melanoplus gladstoni* grasshoppers.

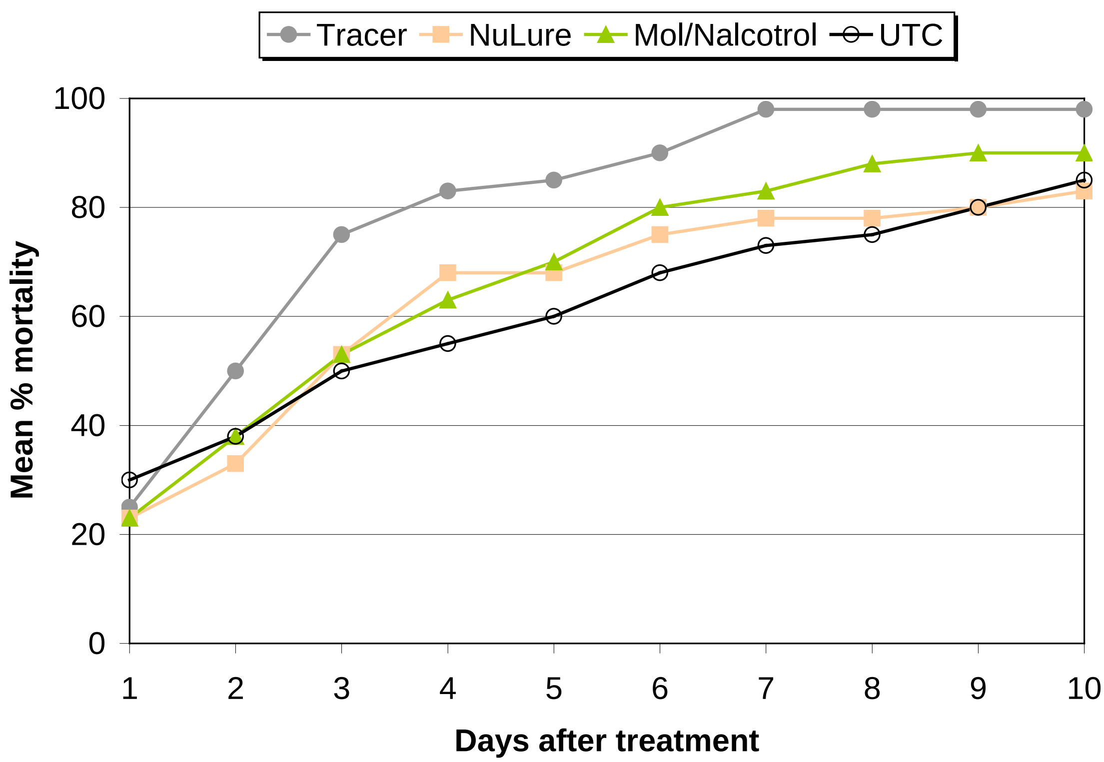

Figure 11. **8 day** residual on grass vs. adult *Melanoplus gladstoni* grasshoppers.

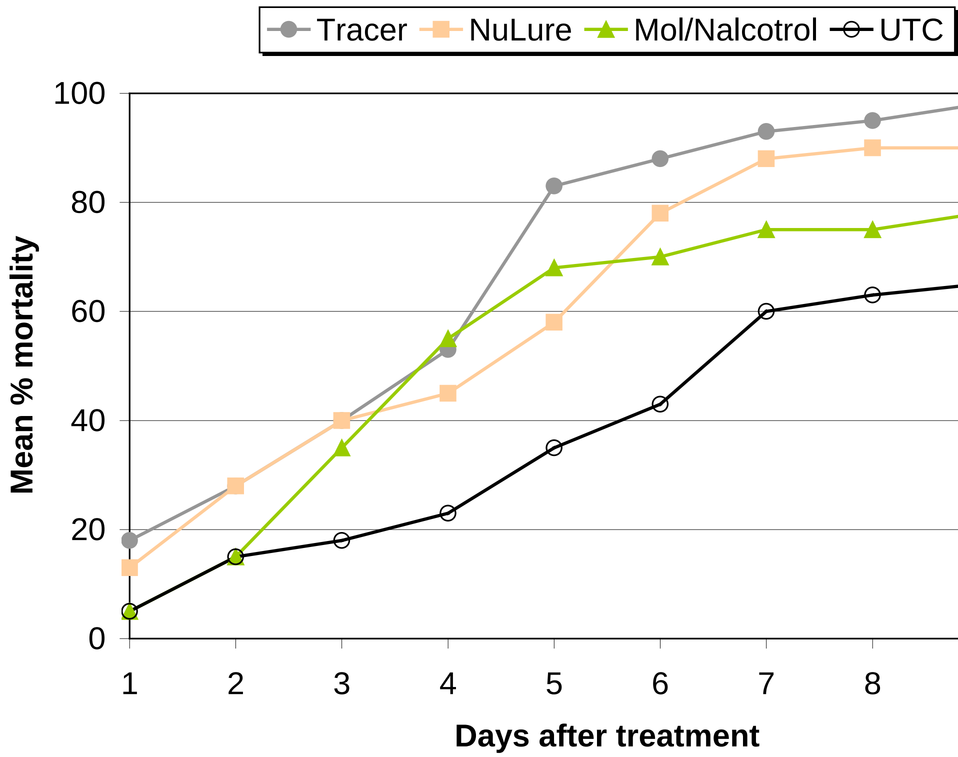

Figure 12. **12 day** residual on grass vs. adult *Melanoplus gladstoni* grasshoppers.

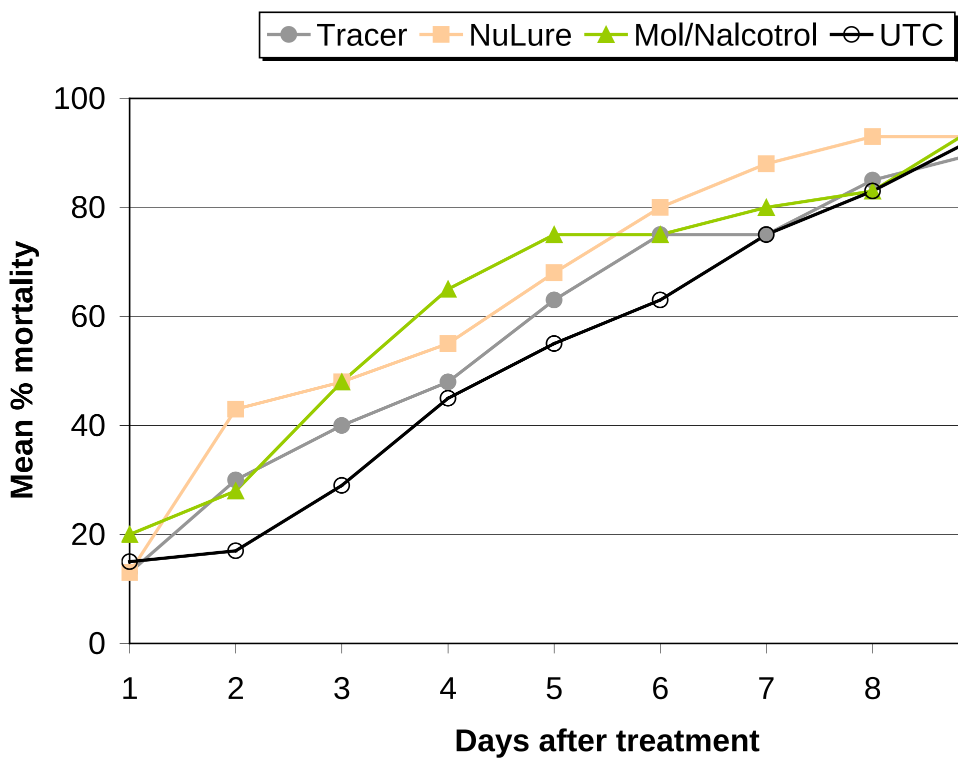

Figure 13. **16 day** residual on grass vs. adult *Melanoplus gladstoni* grasshoppers.

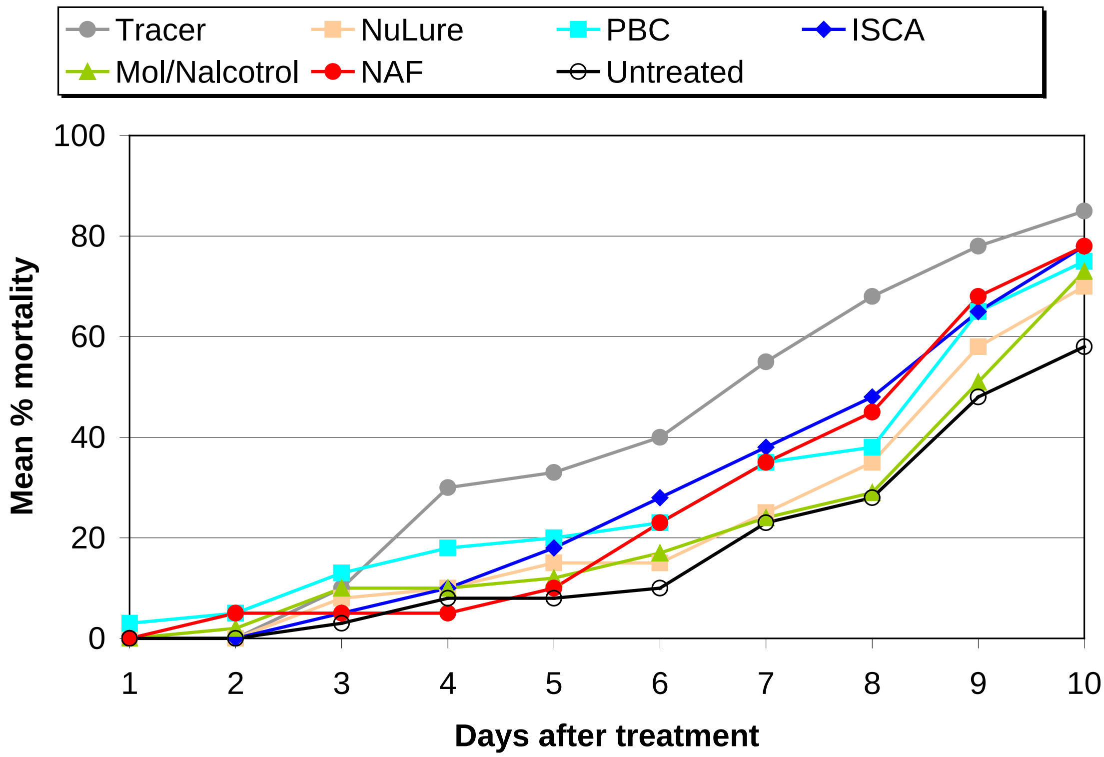

Figure 14. **0 day** residual on grass vs. 5th instar *Melanoplus sanguinipes* grasshoppers.

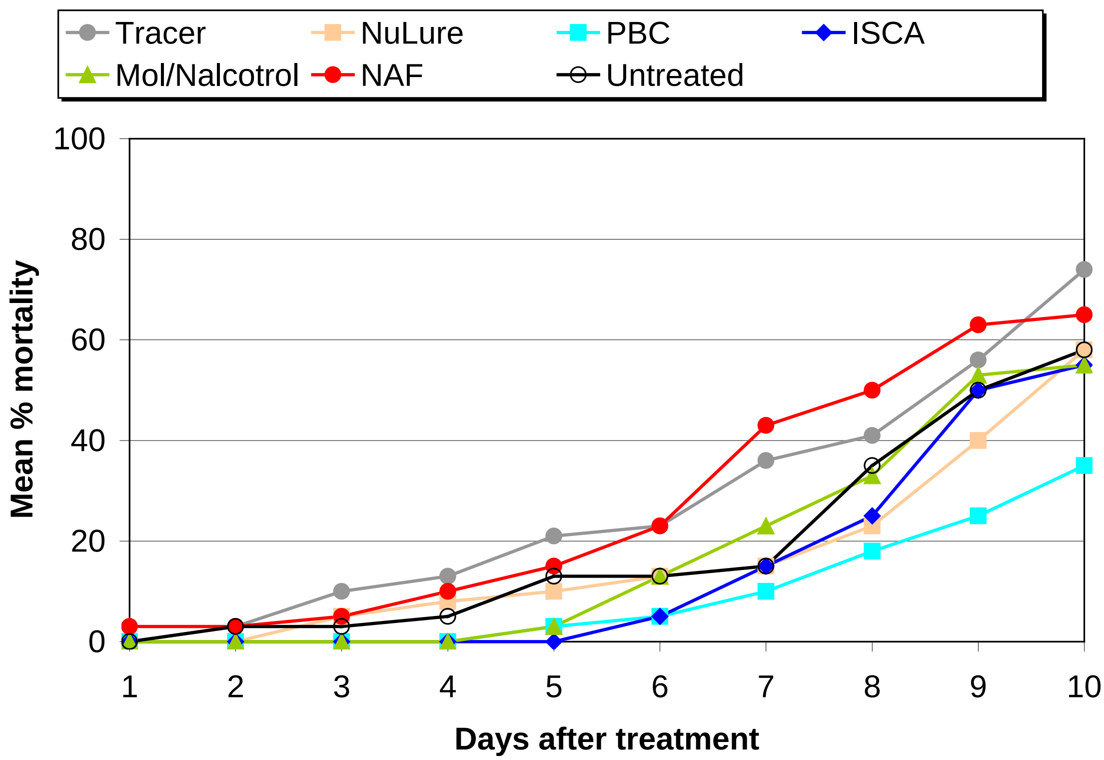

Figure 15. **4 day** residual on grass vs. 5th instar *Melanoplus sanguinipes* grasshoppers.

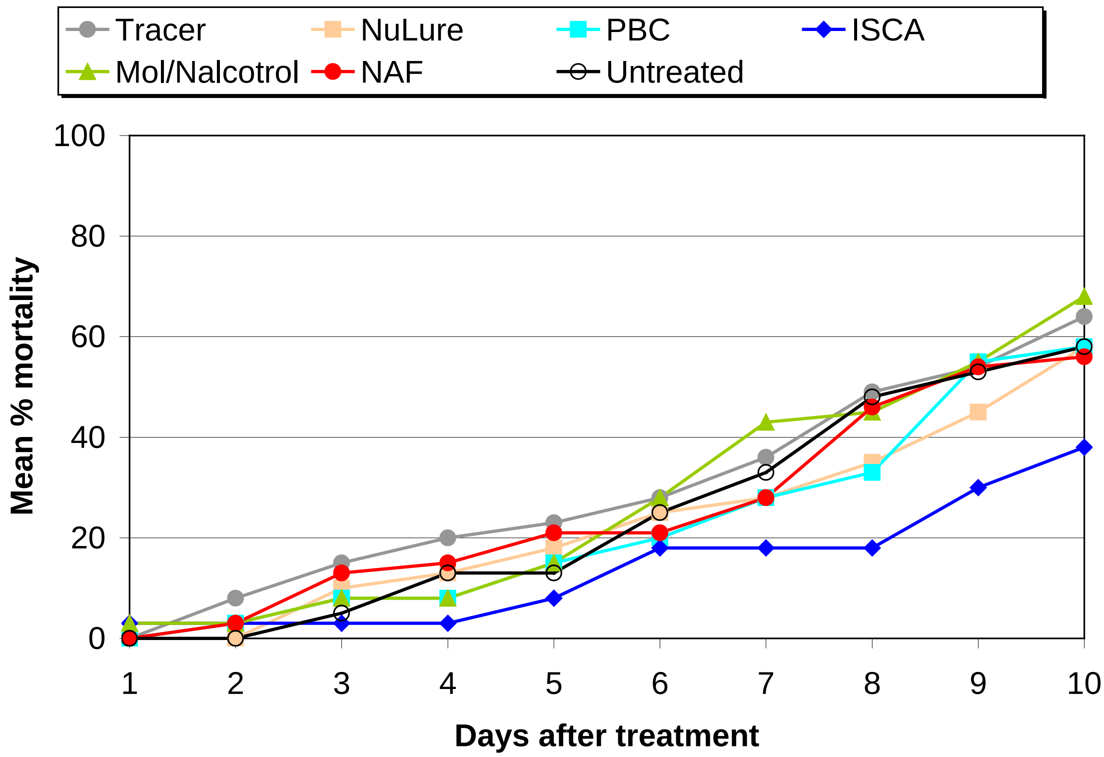

Figure 16. **8 day** residual on grass vs. 5th instar *Melanoplus sanguinipes* grasshoppers.

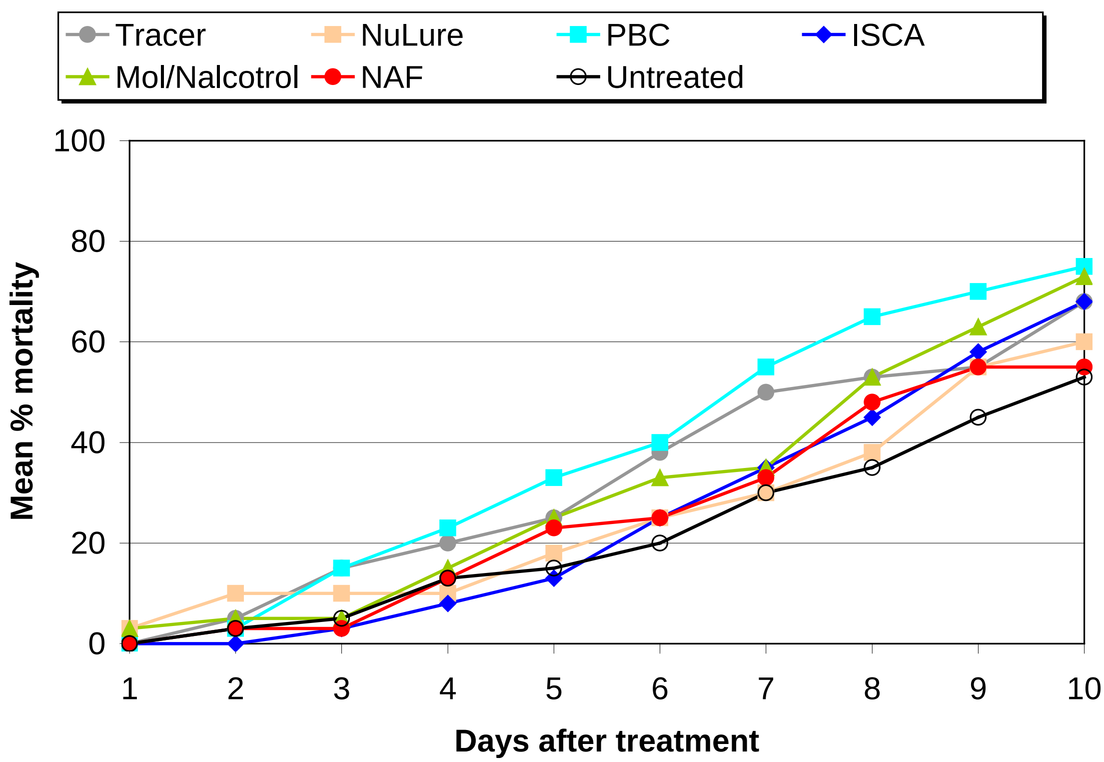

Figure 17. **12 day** residual on grass vs. 5th instar *Melanoplus sanguinipes* grasshoppers.

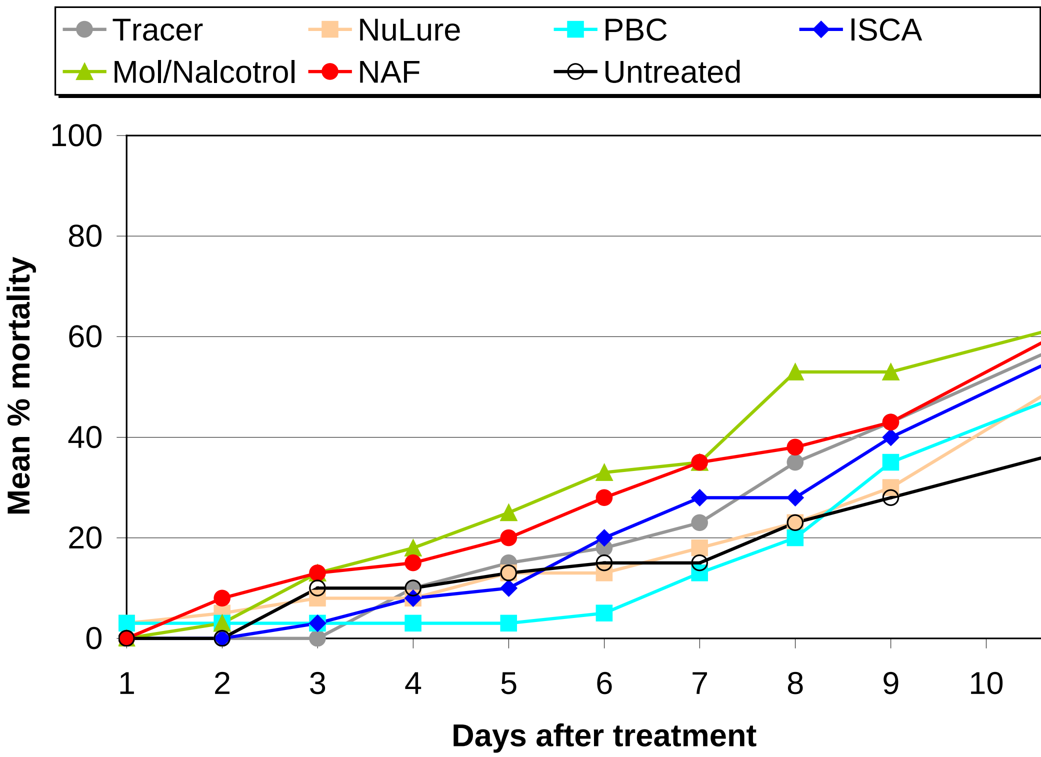

Figure 18. **16 day** residual on grass vs. 5th instar *Melanoplus sanguinipes* grasshoppers.

July, 2008

Manner of pick-up of diflubenzuron by *Ageneotettix deorum* and *Cordillacris occipitalis* (Orthoptera:Acrididae) from aerially sprayed rangeland

R. Nelson Foster[1], K. Chris Reuter[1], Lonnie R. Black[1], Cheryl Huddleston[2], Daryl Hill[3] and Tim Roland[3]

[1]USDA-APHIS-PPQ-CPHST- CPHST Laboratory, Phoenix, Arizona.
[2]USDA, APHIS, PPQ, Pierre South Dakota
[3]USDA, APHIS, PPQ, Aircraft and Equipment Operations, Mission, Texas

Cooperators:
J. Bruce Helbig, USDA, APHIS, PPQ, Pierre South Dakota
Dan A. Largent and Curtis L. Sandberg, Chemtura Corporation
Mark Tubbs, Rancher

Abstract

Mortality on treated rangeland attributable to ingestion, contact, and combined ingestion and contact of diflubenzuron on populations of 4th instar *Ageneotettix deorum* was 96%, 10% and 98% mortality respectively at 14 days after treatment. Similarly, 100%, 24% and 100% mortality resulted on populations of *Cordillacris occipitalis*. Mortality in the untreated populations was 0% and 8% for *A. deorum* and *C. ocipitalis,* respectively for the same period of time. In this study, the mode of entry of diflubenzuron is clear. Mortality can be almost completely attributed to ingestion of sprayed vegetation.

Introduction

Diflubenzuron has been an effective and economical control agent used by the USDA APHIS in control and management of rangeland grasshoppers since 2000 (Foster 2000; Foster et al. 2001; USDA 2002). While it has been generally accepted that that grasshopper mortality arises primarily from the ingestion of diflubenzuron (Wieland et al. 2001), the extent of the mortality attributable to direct deposition of the spray on the insect or ingestion of the spray on vegetation remains undefined. The following experiment was conducted to determine grasshopper mortality levels for the methods of exposure (ingestion of sprayed vegetation, direct deposition of the spray on the insect, and a combination of ingestion and direct deposition) which result from an aerial treatment of rangeland with diflubenzuron. Any mortality attributable to contact between the insect and sprayed vegetation or ground was not determined because of difficulties in preventing the insects from feeding while being exposed to sprayed vegetation. Studies with malathion, another insecticide used for grasshopper control on rangeland, showed that sprayed soil contributed minimally to the total mortality of grasshoppers (Pfadt et al. 1970).

Objectives

1. Determine the level of mortality resulting from a diflubenzuron (Dimilin 2L) treatment that can be attributed to direct impingement contact
2. Determine the level of mortality that can be attributed to ingestion of diflubenzuron (Dimilin 2L) treated vegetation.
3. Compare the ingestion and contact components of total mortality between two common rangeland grasshopper species.

Materials and Methods

A 10 acre (4.05 – ha) mixed grass prairie rangeland plot, treated with diflubenzuron on June 25, 2008 and an adjacent untreated area located ca. 8 miles (12.9 km) north and 10.5 miles (16.9 km) west of Edgemont, South Dakota were selected for the study (Fig. 1). Diflubenzuron was applied aerially as Dimilin 2L (Chemtura Corp. Middlebury CT 06749) to the designated plot at a mix of 1 fluid oz (29.57 ml) dimilin, 10 fluid oz (295.74 ml) of oil (Mo Act- Wilbur-Ellis) and 20 fluid oz (591.47 ml) water/acre. A Cessna AgTruck equipped with (15) 8003 Tee Jet flat fan spray nozzle tips directed straight down at 28 psi (192.5 kPa) with 50 mesh screens, operating at 120 mph (193 kmph) and ca 15 – 20 feet (4.5-6 m high) with a designated and calibrated swath width of 75 feet (22.9 meters) was used for application.

The two most dominant species and their associated dominant stage of development in the plots at the time of treatment were selected for the study. They were, fourth instar *Ageneotettix deorum* (Scudder), a mixed feeder of grasses or sedges, with no clear preference and that can feed heavily on ground litter and fifth instar *Cordillacris occipitalis* (Thomas), another feeder of grasses and sedges that rarely feeds on ground litter (Pfadt et al. 2002).

Two rows of 10 cages (two gallon bottomless buckets modified with screen sides and top) were established for each of two species tested in both treated and untreated plots (total 80 cages). Each row of 10 cages represented 5 replicates with each replicate consisting of two adjacent cages. Rows were separated by ca. 6.56 ft (2 meters) and cages within rows were separated by ca. 3.28 ft (1 meter). Row locations were selected randomly within each plot Cages were stored away from the plots during application to prevent contamination and were placed in the plots soon after application.

Grasshoppers from the untreated area were collected and placed in cages in the treated area to determine ingestion mortality and treated grasshoppers collected immediately after application of the diflubenzuron from the treated area were placed in the non-treated area cages to determine the direct deposition mortality of diflubenzuron. Treated grasshoppers were caged in the treated area to determine the total mortality of diflubenzuron and untreated grasshoppers were caged in the untreated area as a control. Sweep nets were used immediately after application to collect from each plot the grasshoppers which were then placed in two 16 x 16 x 10 inch (36 x 36 x 25.4 cm) screen cages for sorting. Selected grasshoppers were then placed five per container (4 oz (120 ml) specimen cup with screen lid) and transported to the appropriate cages in each plot. All field cages were cleared of grasshoppers before the test grasshoppers were introduced. Each cage was stocked with 5 appropriate grasshoppers.

Mortality percentages were recorded in the cages daily for 21 days following treatment. The mortality values were based on original densities of 10 grasshoppers per 2 cage replication. A one-way ANOV with Tukey HSD Multiple Comparison analysis was used to assess differences between experimental treatments (SPSS, 1997)

Results and Discussion

No differences among any of the treatments were detected for the first four days following treatment of either species. At five days after treatment, the ingestion and ingestion and contact components produced mortality statistically equivalent (12 and 14 % respectively for *Ageneotettix deorum* and 34 and 26 % respectively for *Cordillacris occipitalis*) but significantly greater than produced by contact or the untreated population (4 and 0 % respectively for *A. deorum* and 12 and 4 % respectively for *C. occipitalis)*. This statistical separation remained throughout the study from 5 days after treatment with *A. deorum* and six days after treatment with *C. occipitalis*. While the contact treatment consistently produced numerically higher mortality than occurred in the untreated population at all of the intervals evaluated, at no time during the study was a statistical difference detected. However, this consistent occurrence suggests, the possibility for slight contact activity in other situations or with other species. During our study, mortality in the untreated population of *A. deorum* was 0 % and ranged from 2 to 8% in the *C. occipitalis* populations. Full mortality for both species (96 – 100%) was achieved at about 2 weeks after treatment. The overall mortality encountered during this experiment is similar to that earlier reported on large scale operational studies by Foster et al. 2000, 2004 where mortality of 95 to 98 % occurred at 14 days after treatment.

Similarities in the manner of pickup were apparent between our results with diflubenzuron and those reported with other rangeland grasshopper treatments, malathion (Pfadt et al. 1970), carbaryl (Lloyd et al. 1974) and acephate (Foster et al. 1984). Those toxicants demonstrated that the greatest component of overall mortality results from ingestion of sprayed vegetation. In this latest study, the mode of entry of diflubenzuron is clear. Mortality can be almost completely attributed to ingestion of sprayed vegetation.

Conclusions

Effective levels of control with diflubenzuron against two common rangeland grasshopper pest species occurred at 10 to 14 days after treatment. Clearly, the mortality can be almost completely attributed to ingestion of sprayed vegetation compared to direct impingement contact of spray. These levels of mortality are similar to what have been previously seen in mixed populations of grasshoppers on rangeland treated with diflubenzuron sprays.

Acknowledgements

The authors thank Bruce Helbig and Cheryl Huddleston, USDA, APHIS, PPQ, Pierre and Hot Springs, South Dakota, respectively for assisting in finding the study location. The authors also thank Dan A. Largent and Curtis L. Sandberg, Chemtura Corporation for providing the diflubenzuron used in the study. Special thanks are extended to Mark Tubbs for providing the rangeland for the study and his continuing cooperation since 1989.

References

Foster et al. 2001. Field and Economic Evaluation of Operational Scale Reduced Agent and Reduced Area Treatments (RAATs) for Management of Grasshoppers on South Dakota Rangeland, 1997-1999. *In*: Branson, David H. and Bethany Redlin (eds.) 2001. Grasshoppers: Their Biology, Identification and Management. 1st Edition. CD-ROM. US Department of Agriculture. Agriculture Research Service/Animal and Plant Health Inspection Service/University of Wyoming.

Foster, R. N., K. C. Reuter J. G. Kinzer and J. M. Fisher. 1984. Manner of pick-up of acephate by *Melanoplus occidentalis* (Orthoptera:Acrididae) from aerially sprayed rangeland.

Foster, R. N. 2000. Additional treatment options for consideration when selecting treatments to manage damaging populations of grasshoppers on rangeland. Recommendation Report. April 27, 2000. 9 pp. USDA, APHIS, PPQ, Decision Support and Pest Management Systems Laboratory. Phoenix, Arizona.

Lloyd, J. E., R. E. Pfadt, and M. Ali. 1974. Manner of pick-up of ULV carbaryl by *Aulocara elliotti* from aerially sprayed rangeland. Jour. Eco. Ent. 67: 596-597.

Pfadt, Robert. E. 2002. A Field Guide to Common Western Grasshoppers. 3rd ed. Wyoming Agricultural Experimental Station. University of Wyoming Bull. 912. 288 pp.

Pfadt, R. E., J. E. Lloyd, M. Ali and G. Sharafi. 1970. Manner of pick-up of ULV malathion by grasshoppers from aerially sprayed rangeland. J. Econ. Ent. 63:1210-1214.

SPSS, 1997. SYSTAT for Windows: Statistics, SPSS Inc., Chicago, Illinois.

USDA. 2002. Rangeland Grasshopper and Mormon Cricket Suppression Program, Final Environmental Impact Statement-2002. USDA, MRP, PPQ, APHIS. Riverdale, MD.

Wieland, R. T., F. David Judge, Teun Pels and C. Grosscurt. 2002. A literature review and new observations on the use of diflubenzuron for control of locusts and grasshoppers throughout the world. Jour. Orthopteran Research. 11:43-54.

Figure 1. One of two plots with cages used to evaluate manner of pick-up of diflubenzuron by rangeland grasshoppers near Edgemont, SD 2008.

Figure 2. Fourth instar *Ageneotettix deorum* (Photo by Robert Pfadt 2002)

Figure 3. Fifth instar *Cordillacris occipitalis* (Photo by Robert Pfadt 2002)

Table 1. Manner of pickup mortality of 4th instar *Ageneotettix deorum* on Dimilin treated rangeland vegetation in field cages – Edgemont, SD 2008.

	Days after exposure in cages – mean % mortality																			
Treatment	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Ingestion	2 a	2 a	4 A	12 a	20 ab	36 a	42 a	64 a	78 a	92 a	94 a	96 a	96 a	96 a	96 a	96 a	96 a	96 a	96 a	96 a
Contact + ingestion	0 a	0 a	2 A	14 a	24 a	30 a	38 a	54 a	70 a	84 a	96 a	96 a	98 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a
Contact	0 a	0 a	0 A	4 ab	4 bc	4 b	4 b	6 b	8 b	10 b	10 b	10 b	10 b	10 b	10 b	10 b	10 b	10 b	10 b	14 b
Untreated	0 a	0 a	0 a	0 b	0 c	0 b	0 b	0 b	0 b	0 b	0 b	0 b	0 b	0 b	0 b	0 b	0 b	2 b	2 b	2 c

[1] Means in a column followed by the same letter are not significantly different ($P \leq 0.05$).

Table 2. Manner of pickup mortality of 5th instar *Cordillacris occipitalis* on Dimilin treated rangeland vegetation in field cages – Edgemont, SD 2008.

	Days after exposure in cages – mean % mortality [1]																			
Treatment	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Ingestion	0 a	4 a	10 a	34 a	54 a	70 a	72 a	78 a	86 a	92 a	96 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a
Contact + ingestion	2 a	4 a	10 a	26 ab	42 a	54 a	68 a	80 a	88 a	90 a	96 a	96 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a
Contact	4 a	4 a	12 a	12 bc	16 b	16 b	18 b	22 b	24 b	24 b	24 b	24 b	24 b	26 b	28 b	30 b	30 b	32 b	40 b	48 b
Untreated	2 a	2 a	4 a	4 c	4 b	6 b	6 b	6 b	8 b	8 b	8 b	8 b	8 b	8 c	16 b	26 b	28 b	30 b	46 b	54 b

[1] Means in a column followed by the same letter are not significantly different ($P \leq 0.05$).

August, 2008

Replacing traditional volumes of oil and water in ULV diflubenzuron sprays with alternative diluent mixes for rangeland grasshoppers

R. Nelson Foster[1], K. Chris Reuter[1], Lonnie R. Black[1], Cheryl Huddleston[2], Daryl Hill[3] and Tim Roland[3]

[1]USDA-APHIS-PPQ-CPHST- CPHST Laboratory, Phoenix, Arizona.
[2]USDA, APHIS, PPQ, Pierre South Dakota
[3]USDA, APHIS, Aircraft and Equipment operations, Mission, Texas

Cooperators:
J. Bruce Helbig, USDA, APHIS, PPQ, Pierre South Dakota
Bob Eccles and Wes Hotchkiss, Wilbur-Ellis Company
Dan A. Largent and Curtis L. Sandberg, Chemtura Corporation
Mark Tubbs, Rancher

Abstract

The standard dimilin treatment and experimental treatments containing high and low concentrations of the deposition and drift management agent, In-Place in 12 fl oz and 31 fl oz per acre total application volumes, respectively resulted in equivalent control of grasshoppers on rangeland at 7, 14 and 21 days after treatment. Treatments containing In-Place resulted in remarkably increased flow rates compared to the standard mix. The high concentration of In-Place settles out, is hard to clean up and is considered unacceptable in that form. The handling and clean-up for the lower concentration of In-Place appears acceptable. Results indicate that less than one fl oz of In-Place per acre may replace the need for any kind of oil diluent in diflubenzuron spray mixes. Additional testing is needed and could lead to further reductions in diflubenzuron AI requirements and substantial application and chemical cost reductions.

Introduction

Diflubenzuron, in the Dimilin 2L formulation, has been an ULV option for the USDA APHIS sponsored grasshopper management program since 2000 (Foster et al. 2000; USDA 2002). It was originally applied at 31 total fluid oz (one fl oz Dimilin 2L plus 10 fl oz oil and 20 fl oz water) per treated acre in traditional and RAATS applications (Foster et al. 2001). Since the original registration, mixes of this formulation have evolved to include vegetable oil, paraffinic oil or combinations of both in various ratios. While this flexibility has facilitated greater use, the accompanying inherent complications should be considered. Depending on the brand and/or oil type, different diluents or diluent mixes can exhibit different specific gravities, and flow characteristics that effect equipment calibration. The type of emulsifier used in the preparations can also affect specific gravity, flow characteristics and calibration.

The current label has been modified to allow for lower total volume per acre applications. In ULV applications the label now allows total volumes of at least 12 – 32 fl. oz per acre but requires at least 4 fl oz of emulsified vegetable or paraffinic crop oil per acre, with at least two parts of water for each part of oil. Obviously, the wide range in total per acre diluent use can impact the economics of the treatment. The higher total volume occupies more space in an aircraft hopper (less acres treated per load compared to lower volume treatments) and requires more mixing time. Additionally, more oil increases the diluent cost and mixes of oils can complicate calibration of equipment because various oils and emulsifying agents may require different application parameters.

In an attempt to simplify and standardize the pre-spray mixing and calibration of diflubenzuron spray treatments while improving the economics of diluting materials used in low volume applications for control of rangeland grasshoppers, the following study was conducted.

Objectives

1. Improve the economics of the diluting materials used in diflubenzuron spray mixes.
2. Simplify pre-spray mixing by reducing types and volumes of diluents used with a consistent standard.
3. Simplify calibration by replacing different types and brands of oil diluents (vegetable and paraffinic) and emulsifying agents with a consistent standard.
4. Specifically, compare two concentrations of In-Place (Deposition and drift management agent purported to encapsulate the active ingredient to reduce evaporation and thus increases deposition.) and Mor-Act (adjuvant paraffin base petroleum oil) mixes for ease of use and efficacy.
5. Specifically compare experimental, In-Place and Mor-Acr, diluent mixes with the traditional treatment mix for field efficacy

Materials and Methods

<u>StudySite</u>

The study was conducted in Fall River County of southwestern South Dakota ca. 8 miles north and 10.5 miles west of the town of Edgemont on the Mark Tubbs ranch during the period of June 20 - July 16, 2008. The location was selected because of the diversity in grasshopper species and grasses, density of grasshoppers, recent history of grasshoppers in the area, better than average range condition, and proximity to another proposed study.

<u>Treatments and Experimental Design</u>

The Dimilin 2L formulation of diflubenzuron (Chemtura Corp) was used in all spray treatments studied. The specific treatments were: (1) one fl oz of Dimilin 2L plus one fl oz of In-Place, (deposition and drift management agent – Wilbur Ellis Company) plus 10 fl oz of water – termed low volume In-Place (2) one fl oz of Dimilin 2L plus one fl oz of In-Place plus 29 fluid oz water – termed high volume In-Place and (3) one fl oz of Dimilin 2L plus 10 fluid oz of oil (Mor-Act – Wilbur Ellis Company) plus 20 fluid oz water – termed standard..

All treatments were aerially applied at 100% coverage to square 40 acre grasshopper infested rangeland plots and were replicated four times. Four untreated plots were included in the experimental design for comparison. The replicated study consisted of 16 forty acre plots. To insure that any one treatment was not assigned exclusively to plots with high or low grasshopper densities and that all treatments were tested against similar population densities, pretreatment counts were arranged in descending order and divided into groups of four. Subsequently, each of the 4 treatments, including the untreated control, were randomly assigned to one of the four plots within each group.

The low volume In-Place treatment was applied over a three day period (June 22, 23 and 24) because of wet vegetation and or excessive winds. The high volume In-Place treatment was applied on June 24 and the standard treatment was applied on June 25. All treatments were applied with a Cessna Ag Truck owned by the USDA, Animal and Plant Health Inspection Service (APHIS) and equipped with winglets (DBA- Ag Tips: Clack Oberholtzer, Alberta, Canada). Winglets are added to spray aircraft to reduce the production of fine droplets and to improve handling characteristics. The aircraft was operated by a USDA – APHIS pilot. The aircraft was equipped with a standard commercial spraying system and differentially corrected guidance and recording system (Figure 1). Ground personnel also provided guidance and ensured acceptable operating parameters during application. All applications occurred from an altitude of 30 to 50 feet. Prior to application the aircraft spray system was calibrated to operate under parameters which resulted in delivery of spray within 1% of the desired rate per acre. Calibration was accomplished by collecting and measuring the amount of material sprayed through each nozzle for a predetermined amount of time, and making adjustments in pressure until the desired output was achieved. The aircraft was calibrated for a 75 feet wide swath for all treatments.

The specific mix, total volume applied per acre, number of nozzles, nozzle screen size, nozzle tip size, boom pressure, aircraft speed, and swath width used for each of the 3 different treatments is summarized in Table 1. Winds during application ranged from <1 to 6 mph and averaged 1.9 mph. Ground temperatures did not exceed air temperatures (taken by ground personnel) at any time during applications. Other meteorological conditions recorded during application are summarized in Table 2. The precipitation and daily minimum and maximum temperatures recorded by a temporary weather station established in the treated area for the duration of the study are shown in Figure 2.

<u>Sampling Methods</u>

Generally, grasshopper density and species composition sampling followed protocols established by Foster and Reuter, 1996. Grasshopper populations in treated and untreated plots were counted and sampled 1 to 3 days before treatment and at 7, 14 and 21 days after treatment. Untreated control plots were also counted and sampled on any day a treated plot was monitored. Grasshopper densities were determined by counting grasshoppers in (40) 0.1 m^2 rings (Figure 3) arranged in an approximate 100 yard diameter circle near the center of each 40 acre plot. Rings were separated from adjacent rings by ca, 5 yards.

The abundance of each species was determined from uniform sweep samples taken at each site (Foster and Reuter, 1996). Each sample consisted of 50 high and fast sweeps and 50 low and slow sweeps. Low and slow sweeps performed at ground level insured capture of very young instars and less active grasshopper species while high and fast sweeps performed at the canopy of the vegetation insured capture of older instars and the more active species. Sweep samples were always collected immediately after grasshopper densities had been determined at each site on each visitation. Densities of individual species can be determined by multiplying the frequency of occurrence times the total density of grasshoppers at the same site. After collection, samples were cold stored until they could be sorted and identified in the lab.

<u>Analysis</u>

For the general population, data were expressed as percent mortality based on pretreatment counts in the same plot and were analyzed as such. Additionally, prior to analysis, data was adjusted for the natural population change by the method of Connin and Kuitert (1952) by using the mean values of the untreated plots on the appropriate day. This allowed for converting data from percentage mortality to percentage control and accommodated the natural population change to insure against natural mortality and other environmental factors that affect grasshopper counts, which can confound real differences between treatments.

The adjusted percentage control of the treatment (which takes into account natural changes in the untreated population) was calculated by the formula 100 (1 – Ta x Cb/Tb x Ca), where Tb equals the total population of grasshoppers counted before the plot was treated, Ta equals the total counted after treatment, Cb equals the total counted for the check sites before treatment, and Ca equals the total counted for the check sites after treatment.

An analysis of variance was performed with the Tukey's HSD multiple comparison test used to separate means. All analyses were performed with Systat 6.1 For Windows.

Results and Discussion

Pretreatment densities from individual sites ranged from 13.25 to 43.75 and averaged 28.25 grasshoppers/m^2 in the treated plots and from 16 to 39.5 and averaged 26.25 grasshoppers/m^2 in the untreated plots. At the time of treatment the population was composed predominately of 2^{th} instars (18%), 3^{th} instars (21%), 4^{th} instars (34%) and 5^{th} instars (20%). The total average instar age was 3.496, between third and fourth instar. The age mixture is considered to be very realistic of an ideally timed program treatment. The five most dominant species were *Aulocara elliotti* (38 %), *Ageneotettix deorum* (15 %), *Melanoplus sanguinipes* (12 %), *Cordillacris occipitalis* (12 %), and, *Trachyrhachys kiowa* (8 %) The relative abundance of all species in pretreatment samples is shown in Table 3.

All treatments produced reductions significantly greater than occurred in the untreated population. These reductions were statistically equivalent among treatments regardless of the post treatment interval (Table 4). At 7 days after application, all treatments had reduced populations similarly by 73-77%. At 14 days after treatment (DAT), reductions in treated populations increased, ranging from 93 to 96% but were statistically similar for all treatments. At 21 DAT, reductions remained near the 14 DAT levels and were statistically equivalent. Untreated populations increased during the study by 8, 21 and 9 % at 7, 14 and 21 DAT, respectively. Additional analysis with data adjusted for mortality that occurred in the untreated populations showed similar results (Table 5). The levels of control attained in this study are consistent with earlier studies (Foster et al. 2000) and what is expected of Dimilin treatments correctly applied to control grasshoppers on rangeland.

While there was no difference in mortality resulting from mixes containing low and high volumes or from mixes of low and high concentrations of In-Place, major differences were seen in the handling and clean up phases of the treatments containing In-Place. The high concentration of In-Place treatment resulted in substantial settling of the mix in the hopper of the aircraft overnight and resulted in great difficulty in subsequent remixing and final equipment clean-up. Any settling that occurred with the low concentration of In-Place treatment was considered minimal and clean-up appeared acceptable. While it is not recommended to leave a mixed load overnight in an aircraft, there are times when a prepared load may not be used completely in the day of mixing due to the onset of inappropriate meteorological conditions (wind, precipitation, ground temperatures). In those cases the spray boom must be closed off from the aircraft hopper, the mix drained from the boom and stored back in the aircraft hopper or other storage tank. In either case, our experience in this study indicates that substantial and unacceptable settling of material will occur in the hopper or storage tank and therefore this high concentration of In-Place should not be used. As indicated earlier, the handling and clean-up for the lower concentration appears acceptable.

Because In-Place produced equivalent mortality at both (1:11) and (1:29) dilutions rates with water (but was unacceptable at the highest concentration in terms of settling out and clean-up), one might conclude that an ca. 1:30 ratio with water at the lower total volume application rate of 12 fl oz/ac could produce acceptable results. A candidate mix might be 1:0.33:10.66 oz of Dimilin: In-Place: water. However, industry experts indicate that an equal amount of In-Place and material containing the AI must be used to produce total encapsulation of the AI.

Only further testing under operational conditions will confirm acceptable alternative mixes of Dimilin in terms of handling and clean-up properties and efficacy. Because In-Place encapsulates material to reduce evaporation and thus increases deposition, additional testing is warranted and may lead to further reductions in Dimilin AI requirements and substantial application and chemical costs reductions.

Conclusions

Grasshopper reductions resulting from standard and experimental treatments at all 3 post treatment intervals of time were statistically similar and significantly greater in treated plots compared to untreated populations. Treatments containing In-Place resulted in remarkably increased flow rates compared to the standard mix. Applications with 12 fl oz total volume performed as well as the more traditional treatment with 31 fl oz total volume. However, the low volume (high concentration) of In-Place settles out, is hard to clean up and is considered unacceptable in that form. It appears that using In-Place at 1/29 of the total water use will suffice. However industry experts indicate volumes of In-Place and the neat material must be equivalent for maximum performance. Additional testing is needed and could lead to further reductions in Dimilin AI requirements and substantial application and chemical costs reductions.

Acknowledgements

The authors thank Bruce Helbig for assisting in finding the study location. The authors also thank Dan A. Largent and Curtis L. Sandberg, Chemtura Corporation for providing the diflubenzuron used in the study, Bob Eccles and Wes Hotchkiss, Wilbur Ellis Company, for supplying the In-Place and Mor-Act used in the study and expertise during mixing, respectively. Special thanks are extended to rancher Mark Tubbs for providing the rangeland for the study and his continuing cooperation since 1989.

References

Connin, R. V. and L. C. Kuitert. 1952. Control of the American Grasshopper with Organic Insecticides in Florida. J. Econ. Entomol.. 45:684-687.

Foster, R. N. 2000. Additional treatment options for consideration when selecting treatments to manage damaging populations of grasshoppers on rangeland. Recommendation Report. April 27, 2000. 9 pp. USDA, APHIS, PPQ, Decision Support and Pest Management Systems Laboratory. Phoenix, Arizona.

R. N. Foster, K. C. Reuter, K. Fridley, D. Kurtenbach, R. Flakus, R. Bohles, B. Radsick, J. B. Helbig, A Wagner and L. Jech. 2001. Field and Economic Evaluation of Operational Scale Reduced Agent and Reduced Area Treatments (RAATs) for Management of Grasshoppers on South Dakota Rangeland, 1997-1999. In: Branson, David H. and Bethany Redlin (eds.) 2001. Grasshoppers: Their Biology, Identification and Management. 1st Edition. CD-ROM. US Department of Agriculture. Agriculture Research Service/Animal and Plant Health Inspection Service/University of Wyoming.

Foster, R.N. and K.C. Reuter. 1996. Evaluation of rangeland grasshopper controls: A general protocol for efficacy studies of insecticides applied from the air. In: Cunningham, G.L., and M.W. Sampson tech cords. Grasshopper integrated pest management user handbook. Tech Bull. 1809. Washington, DC: U.S. Dept. of Agriculture, Animal and Plant Health Inspection Service: II.2-1—II.2-7.

USDA. 2002. Rangeland Grasshopper and Mormon Cricket Suppression Program, Final Environmental Impact Statement-2002. USDA, MRP, PPQ, APHIS. Riverdale, MD.

Table 1. Summary of treatments and calibration parameters.

Treatment [1] AI/acre	Coverage %	Dimilin 2L fl oz/ac	Diluent [2] fl oz/ac	Diluent fl oz/ac	Total fl oz/ac	Nozzle no.	Tip size	screen size	pressure psi	Aircraft speed	Swath width
0.016 lbs 7.09 g	100	1.0	1.0 In-Place	10.0 water	12	6	8003	50	28	120	75
0.016 lbs 7.09 g	100	1.0	1.0 In-Place	29.0 water	31	15	8003	50	30	120	75
0.016 lbs 7.09 g	100	1.0	10.0 Mor-Act	20.0 water	31	15	8003	50	28	120	75

[1] Diflubenzuron AI
[2] In-Place is a deposition and drift management agent. Mor-Act is an adjuvant paraffin base petroleum oil.

Table 2. Meteorological conditions recorded during aerial application of treatments in the grasshopper study plots near Edgemont, South Dakota, 2008.

					Temperatures ºF.						
	Plot		Time (AM)		Ground		Air		Pilot	Wind (mph)	
Treatment	no.	Date	Start	End	Start	End	Start	End		Start	End
Dimilin + In Place	9	06/22	5:05	5:20	55	55	57	60	63	1-2 NE	< 1 NE
low volume	13	06/22	5:28	5:42	54	55	56	57	63	2 NE	2-3 S
	19	06/23	6:43	6:55	62	62	65	65	66	1-2 N	5-6 S
	21	06/24	5:02	5:15	55	56	58	57	60	1-1.5 SE	< 1-1 SE
Dimilin + In Place	1&16	06/24	6:03	6:19	52	56	55	60	58	1.5-2 SE	2-2.5 SE
high volume	18	06/24	6:25	6:39	60	60	66	65	61	< 1 S	< 1-1 S
	7	06/24	6:52	7:05	64	65	65	71	61	< 1 SE	< 1 SE
Dimilin standard	17	06/25	5:28	5:40	54	55	58	58	60	2-3 S	< 1 S
	2	06/25	5:45	5:58	55	59	59	60	60	1-1.5 E	< 1 E
	12	06/25	6:11	6:22	59	59	61	62	60	1.5-2 S	1.5-2 S
	14	06/25	6:30	6:42	61	62	62	64	60	2-3 SE	1-2 S
Dimilin std – 10 ac	n/a	06/25	6:55	7:01	64	64	64	65	60	3-4 E	2.5-3 E

Table 3. Grasshopper species composition and age structure prior to treatment near Edgemont, South Dakota, 2008.

	Instar							
Species (20-24 June 08)	1	2	3	4	5	Adult	**Total**	%
Gomphocerinae								
Aeropedellus clavatus				1			1	0.02
Ageneotettix deorum	42	291	354	255	8		950	14.71
Amphitornus coloradus	1	10	59	92	4		166	2.57
Aulocara elliotti	8	57	315	1130	927	8	2445	37.87
Aulocara femoratum	20	89	22	4			135	2.09
Cordillacris crenulata	42	93	24	10			169	2.62
Cordillacris occipitalis		35	85	363	284	15	782	12.11
Eritettix simplex						11	11	0.17
Mermiria bivittata		2					2	0.03
Opeia obscura	7	1					8	0.12
Phlibostroma quadrimaculatum	93	88	12	2			195	3.02
Psoloessa delicatula						47	47	0.73
Melanoplinae								
Melanoplus confusus				1	12	45	58	0.90
Melanoplus infantilis	1	19	16	9			45	0.70
Melanoplus occidentalis		1	1	15	32		49	0.76
Melanoplus packardii			5	3			8	0.12
Melanoplus sanguinipes	68	124	334	267	12		805	12.47
Oedipodinae								
Hadrotettix trifasciatus		21	7				28	0.43
Metator pardalinus		1	17	3			21	0.33
Pardalophora haldemani						3	3	0.05
Spharagemon collare	1	3	2				6	0.09
Trachyrhachys kiowa	99	306	109	9			523	8.10
Totals	382	1141	1362	2164	1279	129	**6457**	
%	5.92	17.67	21.09	33.51	19.81	2.00		

Table 4. Mean percentage mortality of grasshoppers treated with selected diluent mixes of diflubenzuron near Edgemont, South Dakota, 2008.

	Days after treatment – mean % mortality [1]		
Treatment	7	14	21
Dimilin InPlace low rate	73 a	90 a	94 a
Dimilin InPlace high rate	74 a	96 a	95 a
Dimilin standard	77 a	93 a	91 a
Untreated	-8 b	-21 b	-9 b

[1] A one-way analysis of variance was conducted on the primary data. Means in a column followed by the same letter are not significantly different ($P \leq 0.05$) as determined by the Tukey HSD multiple comparison test.

Table 5. Mean percentage mortality of grasshoppers (adjusted for natural mortality) treated with selected diluent mixes of diflubenzuron near Edgemont, South Dakota, 2008.

	Days after treatment – mean % mortality [1]		
Treatment	7	14	21
Dimilin InPlace low rate	75 a	91 b	95 a
Dimilin InPlace high rate	79 a	97 a	95 a
Dimilin standard	77 a	95 ab	91 a

[1] A one-way analysis of variance was conducted on the adjusted data. Means in a column followed by the same letter are not significantly different ($P \leq 0.05$) as determined by the Tukey HSD multiple comparison test.

Figure 1. Aerial application of selected experimental mixes of Dimilin and diluents for control of grasshoppers on rangeland near Edgemont, South Dakota, 2008.

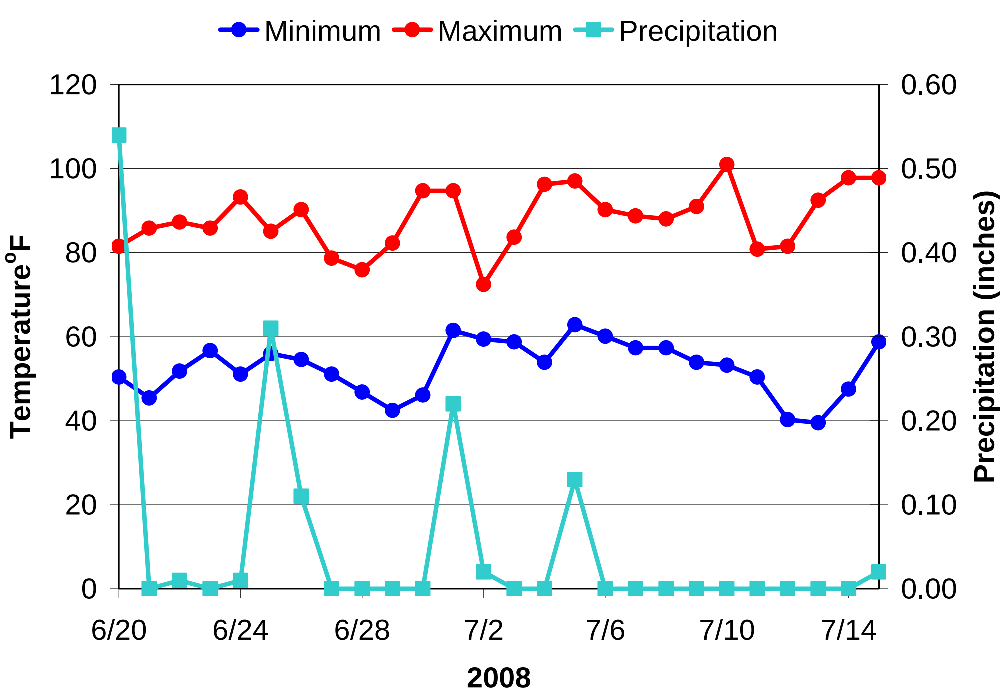

Figure 2. Minimum and maximum temperatures and precipitation recorded at the study area near Edgemont, South Dakota, 2008.

Figure 3. One of forty 0.1 m^2 rings near the center of each plot used to estimate grasshopper densities in study plots near Edgemont, South Dakota, 2008.

July, 2008

Evaluation of incorporating canola oil and dry baits for improving attraction of grasshoppers and bait effectiveness on rangeland

R. Nelson Foster, K. Chris Reuter and Lonnie R. Black

USDA-APHIS-PPQ-CPHST- CPHST Laboratory, Phoenix, Arizona.

Cooperators:

J. Bruce Helbig, USDA, APHIS, PPQ, Pierre South Dakota
Neal Wagner, Peacock Industries, Hague, SK Canada
Gary Saxton, Wilbur-Ellis, Fresno, CA
David I. B. Vander Hooven, Endres Processing Ohio, LLC, Upper Sandusky, OH
Mark Tubbs, rancher, Edgemont, SD

Abstract

Wheat bran, apple pumice and food waste carbaryl baits, containing a canola oil additive were evaluated for improved efficacy against *Cordillacris occipitalis,* a common rangeland grasshopper species categorized as "nonsusceptible' to bait. The addition of the purported grasshopper attractant to the solid baits did not significantly improve acceptance of bait or the resulting efficacy. In two of five different types of analyses conducted, improvement in efficacy was shown at only one of the seven post treatment intervals evaluated, 7 days after treatment. Improvement in bait efficacy due to the addition of canola oil was minimal, if at all, and was considered negligible. Additional studies should be conducted to determine if bait efficacy against "vulnerable" or "sensitive" species can be improved to any significant extent with the addition of canola oil.

Introduction

Various baits (carriers and toxicants) have been used since the late 1800's to suppress grasshoppers and Mormon crickets (Foster 1996). However, since the early to mid 1970's, carbaryl on wheat bran has been the most commonly used bait on western US. rangelands. The level of acceptance by different rangeland grasshopper species to wheat bran bait containing carbaryl is well documented (Onsager et al. 1980 a, b; Quinn et al. 1989, 2000; Jech et al. 1993; Foster et al 1998, 1999). Some species are categorized as "sensitive" where control is expected to average about 70% with worst-case and best-case scenarios about 55% and 85% respectively. Some species are "vulnerable" where control is expected to average about 42% with worst-case and best-case scenarios about 12% and 72% respectively. Some species are categorized as "nonsusceptible" where control is expected to average about 15% with worst-case and best-case scenarios about 0% and 30% respectively (Onsager et al. 1996).

The Mormon cricket, a long-horned grasshopper, is extremely susceptible to wheat bran bait containing carbaryl (Foster et al. 1979). During the last three years, studies with alternative baits based on apple pumice and food waste (combined bakery, snack, cereal and confectionary waste) have shown activity equal to the standard wheat bran bait against Mormon cricket. (Foster et al. 2003, 2004). However, these alternatives did not improve bait efficacy against "vulnerable" or "nonsusceptible" grasshopper species (Foster et al. 2006a,b).

Canola oil has been purported to attract grasshoppers in the field and as a result may possibly improve grasshopper treatment efficacy. Canola oil has been suggested to "enhance the effectiveness of insecticides in grasshopper control programs" (Lockwood et al. 2001) or as a "useful kairomonal adjuvants and/or carrier for acridicide formulations" (Latchinsky et al. 2007). Although, Foster at al. 2004 showed no attractiveness in the field, in terms of increased rangeland grasshopper density, in rangeland strips aerially sprayed with canola oil without insecticide.

To further assess the value of canola oil attraction in grasshopper control treatments and to specifically determine if the efficacy of solid grasshopper baits can be improved by adding canola oil to the baits, the following study was conducted. The study compared the efficacy resulting from three different types of carbaryl based grasshopper baits with and without canola oil for efficacy against a rangeland grasshopper species that is categorized as minimally susceptible to wheat bran bait.

Objectives

Generate additional data on the attraction of grasshoppers to canola oil and the potential value of canola oil in grasshopper treatments in terms of increasing efficacy.

Determine if the efficacy of solid baits for grasshopper species categorized as "nonsusceptible" to wheat bran bait can be improved by adding canola oil.

Specifically, determine and compare in field cages the levels of mortality that result from wheat bran, apple pumice and food waste based baits containing carbaryl with and without the addition of canola oil when applied to control a specific common rangeland grasshopper, *Cordillacris occipitalis.* This species is categorized as “nonsusceptible” to the standard wheat bran bait.

Materials and Methods

The study was conducted in Fall River County of southwestern South Dakota ca. 8 miles north and 10.5 miles west of the town of Edgemont on the Mark Tubbs ranch during the period of July 26-July 3, 2008. The location was selected because of the diversity in grasshopper species and grasses, density of grasshoppers, recent history of grasshoppers in the area, better than average range condition, availability of rangeland without livestock for the time required in the study and proximity to another ongoing study.

The common rangeland grasshopper, *Cordillacris occipitalis*, categorized as “non-susceptible” to carbaryl wheat bran bait (Onsager et al. 1996) and carbaryl apple pumice and food waste baits (Foster et al. 2006b) was selected for field cage evaluation of three baits with and without canola oil. This species was selected because it was the most prevalent “non susceptible” species in the area.

The baits used in the studies were the Sevin Bait (apple pumice “crumbles”, Wilbur-Ellis), Tast-E-Bait (food waste, Endres Processing Ohio, LLC) and the standard, Eco Bran (wheat bran, Peacock Industries Inc.) formulations, each containing 2% carbaryl. Baits containing canola oil were first evenly spread without oil on paper and sprayed with canola oil using an atomizing hand pump sprayer. The bait was sprayed until complete oil coverage of the paper had been achieved. Then the sprayed bait was placed and tumbled in a container for several minutes to ensure uniform mixing. This process was repeated three times for each oil treatment of each bait type.

The experimental design consisted of 5 grasshoppers per cage, 2 cages per replicate and 5 replicates for each of 7 treatments (10 cages per treatment) including the untreated control. This design utilized a total of 70 cages and 350 grasshoppers. Ten cages (two gallon bottomless buckets modified with screen sides and top) were established on rangeland for treatment with each bait type (Figs. 1 and 2). Ten additional cages were established on untreated vegetation as controls for comparison. Each cage was placed on a mix of grasses containing but not limited to, western wheat grass, thread leaf sedge and buffalo or blue grama grass.

The appropriate amount of bait was pre-weighed in the laboratory and introduced into each cage at the rate of 10 lbs/ acre. Five, fifth-instar *Cordillacris occipitalis* (Fig. 3) were captured in an adjacent untreated area, sorted for desired species (Fig. 4) and introduced into cages immediately after bait was applied. After exposure to bait treatments, grasshoppers in all cages including untreated cages were monitored daily for mortality for 7 days (Fig. 5).

Data were expressed as percent survival and were adjusted for the natural population change by the method of Connin and Kuitert (1952) This allowed for converting data from percentage mortality to percentage control and accommodated the natural population change in untreated cages. Percentage control data were converted to rank data (Conover and Iman, 1981). Both unadjusted and adjusted, unranked and ranked data were analyzed using a one-way Analysis of Variance (ANOVA) with the Tukey HSD multiple comparison post hoc test. Analyses were performed with SYSTT for Windows (SPSS Inc. 1997).

Results and Discussion

There was no significant difference in mortality among any of the treatments at any of the post treatment intervals (Table 1, Fig. 6). None of the treatments produced mortality significantly greater than occurred in the untreated populations at any post-treatment interval. Data adjusted for mortality that occurred in the untreated populations and analyzed produced similar results. Yet, some numerical trends seemed to appear. At 5, 6 and 7 days after treatment (DAT), each of the bait types containing canola oil produced higher mortality numerically, compared to its counterpart without oil. However, no trends were seen at the first 4 post-treatment intervals. Additionally, except for one and two DAT, most treatments resulted in numerical mortality greater than in the untreated populations. This low level of mortality attributed to each of the baits without canola oil was not necessarily unexpected. In the "nonsusceptible" category of grasshoppers, which includes *Aeropedellus clavatus*, *Amphitornus coloradus*, *Cordillacris crenulata*, *Cordillacris occipitalis*, *Hesperotettix viridis*, *Metator pardalinus*, *Phlibostroma quadrimaculatum* and *Trachyrhachys kiowa,* control is expected to average about 15% with worst and best case scenarios of about 0% and 30% respectively (Onsager et al. 1996). Although not statistically significant, Foster et al Jan 2006 showed mortality of *C. occipitalis* in response to exposure to 2% carbaryl apple pumice bait to be 30% compared to 8%, 10% and 12% respectively for food waste bait, wheat bran bait and untreated populations, respectively. This compares similarily with the 32% mortality seen in this study at 7 DAT with apple pumice and canola oil. However, bait treatments with canola oil were not necessarily expected to perform as their counterparts. Canola has been touted to be an attractant which might increase efficacy of treatments against rangeland grasshoppers. While this was suggested in terms of increasing feeding on vegetation and or attracting individuals to treated vegetation, a true attractant might be expected to increase mortality with poorly performing species in terms of bait acceptance. Apparently those species (at least *C. occipitalis*) that don't take bait readily, aren't attracted sufficiently to cause adequate consumption of bait to result in increased mortality.

Because trends seemed to suggest an advantage, although slight, with the addition of canola oil the data were pooled for further analysis and evaluation: (1) When the three carriers were pooled and analyzed as bait with and without canola oil in 5 replications with 30 grasshopper observations per replication, no significant differences in mortality were detected at any post treatment intervals. (2) When the three carriers were pooled and analyzed as 15 replicates with and without canola oil and 5 untreated replicates the results showed bait with oil producing significantly higher mortality than bait without oil only at 7 DAT. However, mortality attributed to bait with oil was not significantly higher than what occurred in the untreated population. Additionally, this difference was only detected at one of the 7 intervals analyzed, 7 DAT. (3) Again, when the data were pooled as 15 replicates with and without canola oil and no untreated data was included in the analysis, a significant difference was detected. But as before, this occurred at only one of the 7 intervals analyzed, 7 DAT. In a final analysis where data was adjusted for the mortality that occurred in the untreated population, no significant difference between treatments in terms of mortality, was detected. Because of the minimal if any increase in mortality seen in this study, any improvement in efficacy due to the addition of canola oil is considered negligible.

Conclusions

Data from this study indicates that the addition of canola oil to existing baits (wheat bran, apple pumice or food waste) for rangeland grasshoppers does not improve the efficacy against *Cordillacris occipitalis,* a species considered to be “nonsusceptible” to baits. Only additional studies against other “nonsusceptible” species will unquestionably confirm similar responses of other species in the group. Additional studies should also be conducted to determine if bait efficacy against “vulnerable” or “sensitive” species can be improved to any significant extent with the addition of canola oil. However, until further data to the contrary is developed, it appears that improvement, if any, in bait efficacy that can attributed to the addition of canola oil is negligible against rangeland grasshopper species.

Acknowledgements

The authors thank Bruce Helbig and Cheryl Huddleston, USDA, APHIS, PPQ, Pierre and Hot Springs, South Dakota, respectively, for assisting in finding the study location. The authors also thank Neil Wagner, Peacock Industries, Hague, SK, Canada; Gary Saxton and Joe Millinax, Wilbur-Ellis, Fresno, California; and David I. B. Vander Hooven, Endres Processing Ohio, LLC, Upper Sandusky Ohio, for providing the bait materials used in the study. Special thanks are extended to Mark Tubbs for providing the rangeland for the study and his continuing cooperation since 1989.

References

Connin, R.V. and L. C. Kuitert. 1952. Control of the American Grasshopper with Organic Insecticides in Florida. J.Econ. Entomol. 45: 684-687.

Conover, W.J. and R.L. Iman. 1981. Rank Transformations as a Bridge Between Parametic and Nonparametric Statistics. The American Statistician. 35: (3) 124-129.

Foster, R. Nelson. 1996. Baits for controlling rangeland grasshoppers: An overview. In: Cunningham, G.L., and M.W. Sampson tech cords. Grasshopper integrated pest management user handbook. Tech Bull. 1809. Washington, DC: U.S. Dept. of Agriculture, Animal and Plant Health Inspection Service: II.11-1—II.11-2.

Foster, R. N., C. H. Billingsley, R. T. Staten and D. J. Hamilton 1979. Field cage tests for concentrations of carbaryl in a bait and its application rates for control of Mormon Cricket. Jour. Econ. Entomol. 72: 295-297.

Foster, R. N., K. C. Reuter, D. McNeal and R. McChesney, 2003. Report, Comparison of wheat bran and apple pumice baits for controlling Mormon cricket: Evaluating initial and secondary mortality with baits containing 2% and 5% carbaryl. Nov. 2003. 10 pp.

Foster, R. N., K. C. Reuter, L. R. Black 2006a. Report. Initial evaluation of apple pumice and food waste baits against rangeland grasshopper species not susceptible to the wheat bran bait standard. USDA-APHIS-PPQ-CPHST-DS&PMSL. 11 pp. Jan. 2006.

Foster, R. N., K. C. Reuter, L. R. Black, Bruce Helbig, Lane Kozel and Luke V. Schuetzle. 2006b. Field cage comparisons of wheat bran, apple pumice and food waste baits containing carbaryl against rangeland grasshopper species with varying susceptibilities to standard wheat bran bait. USDA-APHIS-PPQ-CPHST Lab. Phoenix, AZ. 12 pp. Sept. 2006.

Foster, R. Nelson, Stephan Jaronski, Chris Reuter, Bruce Helbig, John Bradley, Cheryl Huddleston, Bryan Fitzgerald, Julie Grace and Bruce Radsick. 2004. Evaluation of the fungus *Beauveria bassiana* in canola oil and paraffinic oil and identifying the low dose of a bacteria derived toxin, spinosad, for use against rangeland grasshoppers. USDA-APHIS-PPQ-CPHST-DS&PMSL. 33 pp. April 2004.

Foster, R. N., K. C. Reuter, L. R. Black, D. McNeal, and R. McChesney. 2004. Report Comparison of wheat bran, apple pumice and a combined (bakery, snack, cereal and confectionary) food waste baits containing carbaryl for controlling Mormon crickets: Studies of bait longevity and primary and secondary mortality. USDA-APHIS-PPQ-CPHST-DS&PMSL. 12 pp. OCT 2004

Foster, R. N., M. A. Quinn, L. L. Herbaugh, D. D. Walgenbach, R. L. Bohls, K. C. Reuter, and T. J. Roland. 1998. Effect of multiple concentrations and rates of an insecticidal bait on grasshoppers (Orthoptera: Acrididae) of mixed-grass prairie. Jour. Kansas Entomol. Soc. 71: 1-10.

Foster, R. N., M. A. Quinn, K. C. Reuter, D. Colletto, R. Houston, M. J. Puclik, A. Scott, and B. Radsick. 1999. Comparison of single and multiple applications of an insecticide bait for controlling grasshoppers (Orthoptera: Acrididae) on mixed-grass prairie. Jour. Kansas Entomol. Soc. 72: 181-189.

Jech, L. E., R. N. Foster, D. Coletto, D. D. Walgenbach, T. J. Roland, G. D. Rodriguez, R. Bohls, R. D. Houston, W. K. Meeks, R. L. Queener, C. L. Jackson, J. L. Dines, M. K. Puclik, and A. K. Scott. 1993. Field evaluations of diflubenzuron and carbaryl bran baits against grasshopper (Orthoptera: Acrididae) populations in South Dakota. Jour. Econ. Entomol. 86: 557-565.

Latchininsky Alexander V., Scott Schell and Jeffery A. Lockwood. 2007. Laboratory Bioassays of Vegetable Oils as Kairomonal Phagostimulants for Grasshoppers (Orthoptera:Acrididae). J. Chem. Ecol. 33:1856-1866.

Lockwood, Jeffrey A. , Narsu, Scott P. Schell and Dale R. Lockwood. 2001. Canola oil as a kairomonal attractant of rangeland grasshoppers: an economical liquid bait for insecticide formulation. International Journal of Pest Management.47;185-194.

Onsager, J. A., J. E. Henry, and R. N. Foster. 1980a. A model for predicting efficacy of carbaryl bait for control of rangeland grasshoppers. Jour. Econ. Entomol. 73: 726-729.

Onsager, J. A., J.E. Henry, R. N. Foster, and R. T. Staten. 1980b. Acceptance of wheat bran bait by species of rangeland grasshoppers. Jour. Econ. Entomol. 73: 548-551.

Onsager, J. A. and R. N. Foster. 1996-1999. Bait Acceptance by Different Grasshopper Species and Instars. In: Cunningham, G.L., and M.W. Sampson tech cords. Grasshopper integrated pest management user handbook. Tech Bull. 1809. Washington, DC: U.S. Dept. of Agriculture, Animal and Plant Health Inspection Service: II.12-1—II.12-5.

Pfadt, Robert E. 2002. A Field Guide To Common Western Grasshoppers. 3rd ed. Wyoming Agricultural Experiment Station. University of Wyoming. Bull. 912. 288 pp.

Quinn, M. A., R. L. Kepner, D. D. Walgenbach, R. A. Bohls, and P. D. Pooler: R. N. Foster, K. C. Reuter, and J. L. Swain. 1989. Immediate and 2nd-year effects of insecticide spray and bait treatments on populations of rangeland grasshoppers. Canadian Entomologist. 121: 589-602.

Quinn, M. A., R. N. Foster, W. J. Cushing, D. C. Hirsch, K. Winks, and K. C. Reuter. 2000. The North Dakota grasshopper integrated pest management demonstration project. U.S. Dept. Agri. APHIS. Tech. Bull. 1891. 124pp.

SPSS Inc. 1997. SYSTAT for Windows: Statistics, SPSS Inc., Chicago, Illinois.

Figure 1. Bucket cage used in evaluating baits for rangeland grasshoppers.

Figure 2. Setup for evaluating selected grasshopper baits in one of two separate cage studies near Edgemont, South Dakota, 2008.

Figure 3. Fifth instar *Cordillacris occipitalis* (Photo by Robert Pfadt 2002)

Figure 4. Selecting the appropriate grasshopper species from sweep net collections for placement in cages.

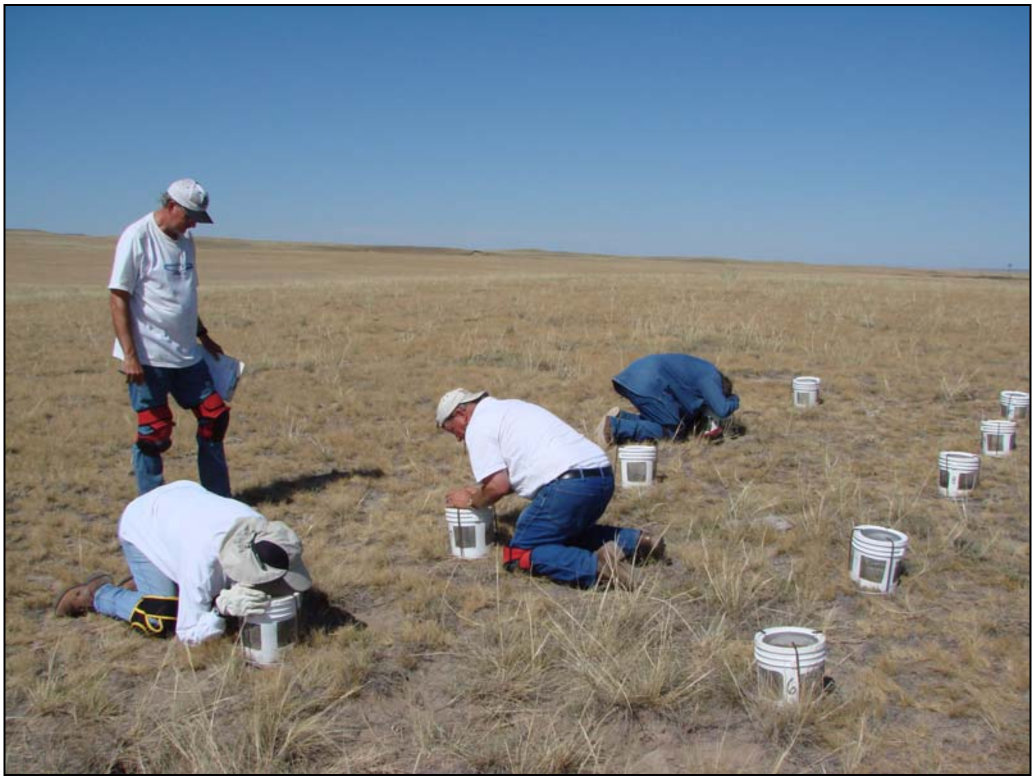

Figure 5.   Monitoring bucket cages used in evaluating grasshopper baits.

Figure 6. Evaluation of 2% carbaryl bait with and without canola oil against *Cordillacris occipitalis* in field cages – Edgemont, SD 2008.

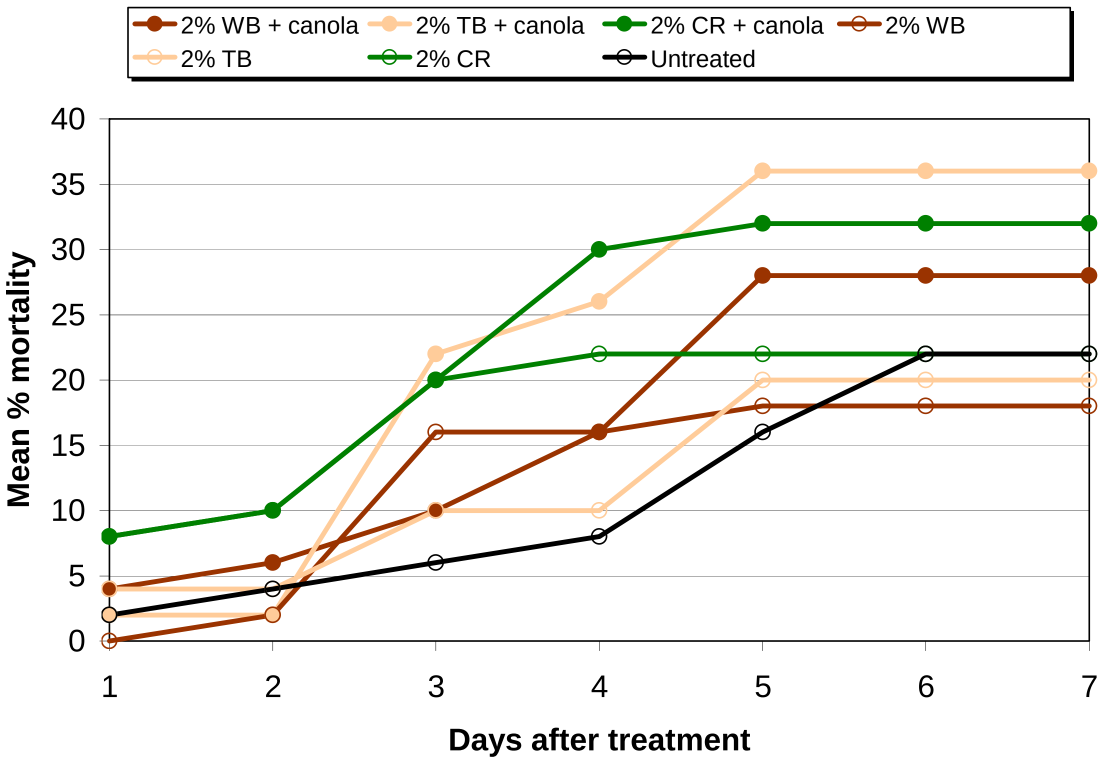

Table 1. Mortality of 5th instar *Cordillacris occipitalis* exposed to selected carbaryl baits with and without canola oil in field cages – Edgemont, SD 2008.

	Mean % mortality[2] – days after treatment						
Treatment[1]	1	2	3	4	5	6	7
2% WB + canola	4a	6a	10a	16a	28a	28a	28a
2% TB + canola	2a	2a	22a	26a	36a	36a	36a
2% CR + canola	8a	10a	20a	30a	32a	32a	32a
2% WB	0a	2a	16a	16a	18a	18a	18a
2% TB	4a	4a	10a	10a	20a	20a	20a
2% CR	8a	10a	20a	22a	22a	22a	22a
Untreated	2aa	4a	6a	8a	16a	22a	22a

1WB, TB, and CR = wheat bran, food waste, and apple pumice baits respectively.
2Means in a column followed by the same letter are not significantly different ($P \leq 0.05$).